REVOLUTIONIZING THE COMMERCIAL MARKETPLACE

By Dr. James Richardson

For 50 years DARPA has been noted for its innovation in conceiving and developing some of the most exciting and high-payoff technologies used by our military. Not as widely recognized are the profound ways in which many of those technologies have also changed civilian lives and made an impact on the commercial marketplace. DARPA's military technology search has been greatly enhanced by its unique partnerships with commercial companies. Part of DARPA's remarkable story concerns how this Department of Defense (DoD) agency has employed its creative powers to fashion business and program management techniques necessary to attract the skills and efficiencies of commercial businesses. These techniques have proven so successful and apt for this era that they have proliferated throughout the DoD, and are now being used in all military services.

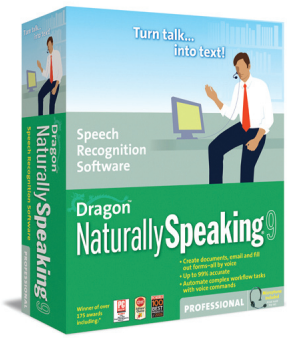
INTRODUCTION

I sit at my computer writing, or rather dictating, this article through voice-to-text software that is managed and sold by Nuance Communications, Inc. The product line actually began, before a string of mergers and buyouts, when a small company, Dragon Systems, created code under DARPA sponsorship. Its aim was to combine voice recognition with translation to facilitate communication in foreign combat zones. The basic voice recognition code has proliferated throughout the commercial market as "Dragon Naturally Speaking," while the translation software has been employed under numerous military scenarios around the world. This work is continuing at DARPA and is likely to further improve voice-to-text and communication in both communities – civilian and military.

The above illustrates just one of the many ways in which DARPA has affected people's lives worldwide. But the Nuance/Dragon example also exemplifies two business strategies through which DARPA has co-opted commercial industry to develop militarily significant advanced technologies for the DoD.

The first strategy was based on the recognition that for many areas of technology development, budgets, skills, and efficiencies were far superior in the private sector than in either the defense industry or DoD laboratories. Yet, because of differences in attitudes and values between government and private industry, new ways of contracting and program management were needed to bring the two together. DARPA developed radical ideas that have served well over the years to do exactly that.

Part of DARPA's problem was finding motivations to encourage private industry to participate in DoD technology development. The second strategy focused on this task, applying an existing concept called "dual use:" the production of items that are useful to both the civilian and military communities. As we shall see later, DARPA broadened the idea of dual use to include technology development, rather than simply furnishing off-the-shelf products. The formulation of both these strategies has demanded the same high levels of innovation that have made DARPA so successful in advancing military technologies and systems.



"Dragon Naturally Speaking" software is derived from code that Dragon Systems created under DARPA sponsorship.

DARPA'S CONTRIBUTIONS TO THE COMMERCIAL MARKETPLACE

Although the following examples of DARPA's successes in influencing the civilian sector are impressive, it is important to note that this sector is only a target when it facilitates military transitions and use of the agency's products – DoD relevancy is always central to DARPA's programs.

Nuance Communications Inc. image

There are few rivals for military interest and budget that can compete with information technology. Yet as important as information technology investments have been to defense, advancements in this area have absolutely revolutionized civilian lifestyles. DARPA's role in bringing about this revolution is commonly known, even by those who are relatively unfamiliar with the agency.

Internet. Of course, one must begin with the Hope diamond of DARPA's contribution to the world, the ARPANET, precursor to the Internet. If no other product had resulted from the DARPA experiment begun 50 years ago, this one achievement would have justified the effort. Even admitting the credibility of the view that it would have eventually emerged from the maelstrom of information technology development activities, the Internet may well have taken too long or, if produced by a single company, may have been smothered with proprietary restrictions that were avoided by its birth in DARPA and the National Science Foundation.

Distributed computing. This came on the heels of ever-larger central computer systems that essentially left the public out. Even though time-sharing was improving, few could have afforded, or would have had the interest, to access a bureaucratically managed and massively time-shared machine. The creativity of the U.S. computer industry solved that problem with the personal computer, the PC – and DARPA was a principal sponsor of this work. Rapid improvements in capability, efficiency, and user-friendly software led to its pervasive use today – there were an estimated 239 million PCs in the United States in 2005 – and to remarkably changed lifestyles.

Other software advancements. DARPA sponsorship led directly to such innovations as Unix; Windows NT; packet switching; TCP/IP protocols; reduced instruction set computing; massively parallel processing; computer-aided design/computer-aided manufacturing, synchronous optical networking, asynchronous transfer mode, computer graphics, and other products. Like the ARPANET, these essentially dual-use technology creations have changed the world, from the home and office to the battlefield.

Other hardware advancements. Hundreds of commercial companies conducted programs in semiconductor modeling, design, and fabrication that, once again, served the military as well as the commercial world. Particularly vital were the advancements in integrated circuit design and manufacturing, which led to products like personal computers and very large-scale integration.

The Pictorial Archiving Communications System (PACS). A development under the Technology Reinvestment Project (TRP) – a discussion of which appears later in this article – this system is used in almost all DoD hospitals with digital imaging, replacing hard-copy-based means of managing medical images, such as film archives. By 1999, the PACS was operating in 29 civilian hospitals around the world. PACS technology is now offered by virtually all the major medical imaging equipment manufacturers, medical information technology companies, and many independent software companies. The system allows remote site and collective viewing and diagnosis as well as dramatically reducing necessary storage space.

General Electric Digital X-ray (a TRP development). When DARPA Program Man-

DARPA has worked with private-sector contractors to improve night-vision equipment used by both the military and civilians. Pictured above is a night-vision, close-up view of a U.S. Army soldier, wearing a Kevlar helmet with night-vision goggles attached, as he prepares for a night operation in Iraq.

U.S. Army photo by Spec. Olanrewaju Akinwunmi

ager Dr. Frank Patten began negotiations with General Electric (GE) on a program to replace film in X-ray systems with digitizing panels, he was told that DARPA's small cost-sharing offer would never change the plans of a multi-billion dollar company. But Patten and the head of GE's medical division overturned corporate headquarters' initial decision not to fund the effort. The next question was panel size. While GE wanted to build a small arterial diagnostic device, Patten held out for a panel of sufficient size to allow whole chest X-rays needed to analyze battlefield wounds. GE agreed and, after 11 years and $130 million in investments, military and civilian hospitals around the globe have profited from the results, which include the only Food and Drug Administration-approved mammographic digital detector.

Two uncooled infrared technologies – microbolometer and ferro-electric (a TRP development). DARPA and the Army's Night Vision Laboratory had pursued uncooled infrared (IR) technologies for some years when the TRP offered another opportunity. With Ray Balcerak as the program manager, several contractors responded and by the end of the program, prototypes were ready for both commercial and military market assessment. As early as 1999, over 1,000 of these systems were in use in such roles as security and driver's night-vision devices. Other models were tested for mine detection, thermal weapons sights, and terminal guidance. DARPA's progress continues in this vital technology area. Uncooled IR, with its increasing advantages of weight and cost over cryogenically cooled sensor systems, has become all but ubiquitous in the commercial marketplace in numerous roles: security and law enforcement, production and power system monitoring, and assessment of thermal insulation.

Recently, under DARPA direction and sponsorship, DRS Technologies developed high-performance, low-cost uncooled microbolometer focal plane arrays that are in production for DoD systems application. Examples of DoD systems using DRS's 25-micrometer pixel 640 x 480 (30Hz) and 320 x 240 (60 Hz) uncooled focal plane arrays are the Army's Thermal Weapon Sights and Driver Vision Enhancers and Air Force UAVs.

Currently, amorphous silicon alloy materials and low thermal mass detector technology developed under the DARPA HOT program are enabling the development of a new generation of high-resolution, uncooled infrared megapixel focal plane arrays. The low-noise, high-temperature coefficient of resistance amorphous silicon alloy materials development has allowed the reduction in pixel size from 25 microns down to 17 microns. This enables the thermal imaging demonstration of the megapixel-class 1024 x 768 focal plane array, the world's first uncooled focal plane array that is larger than 640 x 480.

Furthermore, the HOT program has funded the development of a novel low thermal mass detector design that permits this new megapixel class of arrays to image with response times less than 5 milliseconds over the mid- and long-wavelength infrared spectral bands. This high-speed capability eliminates image smear in scenes with fast-moving content and opens up the potential for fast-event (e.g., muzzle flash) detection. These large format arrays have applications in the commercial roles mentioned above as well as military uses in persistent surveillance and traditional individual warfighter operations.

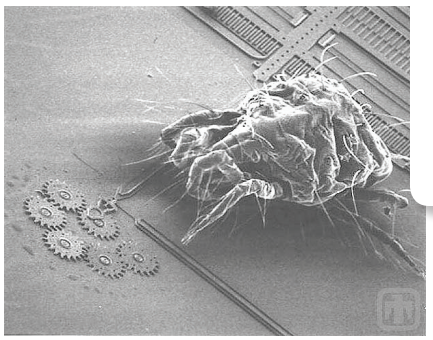
Optoelectronic modules (OEM) (a TRP development). Dr. Robert Leheny sponsored a consortium led by Lucent that was formed to develop an Integrated Opto-Electronic Module (IOEM) to integrate optical and electrical components into a monolithic IOEM to reduce cost. The military first used the IOEM in a low-cost fiber optic gyro (FOG) made by Fibersense Technology. Fibersense won an Army contract to replace the mechanical gyros in the Bradley Fighting Vehicle with the smaller, lighter weight FOG and also joined Allied Signal in a major Navy guided munitions program to deliver 300 FOGs during the development phase. At this time, Lucent was also using the technology to address the commercial market area known as Fiber-To-The-Home (FTTH). Based on the outcome of this project, Lucent was able to negotiate a $6 billion joint development program with Nippon Telegraph and Telephone to complete adaptation of their IOEM for FTTH markets in Japan.

In a second OEM effort managed by another DARPA program manager, an analog optoelectronic modulator was inserted into a DoD program by Uniphase Telecomm Products for the fiber-optic transmitter of the Lockheed-Sanders Integrated Defensive Electronic Countermeasures system with plans to equip over 1,000 aircraft. The modulator was also selected by TRW Defense System for antenna remoting application. A number of other analog optoelectronic modules developed on the project were successfully employed in a demonstration of ultra-wideband shipboard electromagnetic environment monitoring demonstration on the USS *Princeton*. A commercial sale of 1,000 optoelectronic modulator units enabled wireless communications systems and antenna remoting for communication satellite ground stations.

Microelectromechanical Systems (MEMS). Perhaps one of the next big dual-use contributions by DARPA will be in MEMS technology. In a 2007 interview with former agency Director Larry Lynn, he explained, "MEMS came along during [the late 1980s,] reaching maturity and building very, very tiny systems on a chip. The ability to build mechanical systems with … electronic systems in a customary way [and with] optical systems, all on the same chip, allows you to think in terms of systems on a chip where you have whole problems solved that way. And you begin to see those even in consumer electronics today." The agency began sponsoring MEMS development during the 1990s under Dr. Ken Gabriel, who managed DARPA's MEMS programs from 1992 to 1997. One of the first DARPA MEMS applications came from the TRP effort discussed below. High Aspect MEMS technology was chosen for the baseline design of a Naval Surface Weapons Center safety and fuzing device for its Submarine Torpedo Defense and as an upgrade for the Mark 48 torpedo.

Today, MEMS appears in amazingly diverse products and is becoming more pervasive as cost, reliability, and packaging improve. Although DARPA cannot be credited for sponsoring the invention of MEMS, it certainly helped to move this technology along the path toward widespread application in both commercial and military systems. The agency's work continues, and at DARPATech 2007, Dr. Amit Lal, program manager in the Microsystems Technology Office, spoke of a revolution in both MEMS and its little sister, nanoelectromechanical systems (NEMS):

> We see the metamorphosis in televisions with digital light processing technology and its reliable million-mirror arrays, enabling television imaging to proliferate from walls to eyeglasses. We hear it in our mobile phones as large quartz resonators for timing references are replaced by micromechanical resonators, opening up space for more functions in our cell phones … MEMS inertial measurement units, or IMUs, are being used to improve the accuracy and reliability of pre-



DARPA began sponsoring MEMS development in the 1990s, and the technology has both military and commercial applications. Left: A scanning electron microscope image of a spider mite on a polysilicon MEMS gear train. MEMS allow entire systems to be built on tiny chips. Right: A MEMS-enabled fuzing device for a torpedo.

Photo courtesy of DARPA

Sandia National Laboratories

cision weapons, such as JDAMs, reducing collateral damage and reducing the number of weapons.

Lal went on to discuss amazing future MEMS and NEMS applications, such as enlisting MEMS motion control into robotic surgery and a revolution enabled by NEMS switches in super-efficient, high-temperature computing.

According to Paul McWhorter, formerly of Sandia National Laboratories, some commercial applications of MEMS are: automobile air bag accelerometers that have reduced costs per unit – from $50 to less than $10 – and which are fast enough to save many more lives than conventionally employed accelerometers; pressure sensors; high-performance, steerable micromirrors; radio frequency MEMS devices (such as switches); disposable medical devices; and secure communications.

COMMERCIAL SECTOR CONTRIBUTIONS TO THE MILITARY: HOW DARPA CHANGED THE RELATIONSHIP BETWEEN THE PRIVATE SECTOR AND MILITARY

Now we turn to the flip side of commercial benefits of DARPA-funded technologies and examine advantages to the military of including private-sector researchers. Because DARPA's potential customer base includes mission areas across all military services, the breadth of the problems and solutions encountered is well out of proportion to the agency's size. The problems posed by this large and diverse community and a mandate to find highly innovative and state-of-the-art technical solutions have expanded the agency's search for an increasingly wider swath of ideas well beyond the military industrial complex to academia and the private sector. The last of these has grown in importance because of at least three factors.

First, the private sector has been assuming a growing portion of the budget burden, surpassing government expenditures since the late 1970s. For years, government R&D spending – mostly by the DoD – eclipsed that of the private sector. But industry began heavily investing in R&D, mainly on the development side, and in 1979 the total industrial R&D budget surpassed that of the federal government; that trend has not diminished. This change in the funding landscape led to a much larger portion of technology contributed by commercial researchers, which naturally gained the interest of an entrepreneurial technology harvester like DARPA.

Second, civilian technologies in telecommunications, computers, and biology became consequential to the military equation. For example, military emphasis on terms such as "network-centric warfare," "self-healing networks," and "reliable and secure communications" bear evidence of the importance of these commercial market-based industries.

Finally, including the commercial industry presents significant advantages to the military (e.g., access to expanded knowledge and skill bases, faster programmatic response, reduced cost, and improved quality). Considerations of these advantages led to the agency's acute attention to commercial-sector R&D, and closer ties with the commercial sector and marketplace also resulted in numerous commercial products.

DARPA has employed two strategies to convince commercial industry to work with DARPA.

DUAL-USE TECHNOLOGY DEVELOPMENT

Technologies or systems that would appeal to both the commercial and military marketplaces can be developed by defense contractors, private-sector companies, universities, or by a consortium composed of participants from all three. The resulting products, called "dual-use technologies," can provide immense benefits to both markets. Of course, food, clothing, medical supplies, and many other commodities have always been purchased by the military services directly from the civilian economy. These are called "commercial off-the-shelf," or COTS in military jargon. Even military systems, such as vehicles, have been procured as "non-development items." For DoD's procurement world, this was an obvious way to gain from the efficiencies and economies of scale found in the U.S. manufacturing and production industry.

DARPA's strategy begins well before procurement. For those selected technologies that could lead to products useful to the military, the agency sometimes agrees to begin government sponsorship during the technology development phase. This strategy has paid off well because of the growing applicability of civilian technoogies from such fields as electronics, information systems, materials, and medicine, to military missions. Early realization of this important trend allowed DARPA to harness superior commercial R&D skills in certain areas of technology. Ultimately, the advantages to the DoD were the same as those produced in the dual-use procurement strategy – less costly and better products that served the military more effectively through commercial production efficiencies and economy of scale.

The Technology Reinvestment Project. By the 1990s, the efficacy of dual-use technology was generally recognized. The benefits of the private sector's innovation, economy of scale, and rapid and reliable production were well demonstrated. As a result, the Defense Conversion, Reinvestment, and Transition Assistance Act of 1992 led to the establishment of a program designed to maximize the benefits of dual-use technology. The program was named the Technology Reinvestment Project, the TRP, and was placed under the management of DARPA because of the agency's extensive experience in dual-use technology development. Both the Clinton administration and Congress publicly embraced the concept of the TRP. The program was first led by Dr. Lee Buchanan, then-director of DARPA's Defense Sciences Office, and later by Dr. Steve Wax.

At close to $1 billion, the program became one of the largest commercial investment efforts ever undertaken by the DoD. DARPA was required by Congress to work in concert with other government agencies. Program participants from the Army, Navy, and Air Force helped ensure that the TRP focused on military problems and benefits. In addition, high-ranking officials from other federal departments were also included.

Through three solicitations held in FY 1993, 1994, and 1995, the TRP sponsored 133 dual-use technology development projects. But the TRP encountered problems on Capitol Hill. A new, Republican-dominated Congress decided that the program constituted more value for commercial industry than for the military and closed it down. The last TRP solicitation was held in 1994, but TRP's products continued to emerge for years to follow.

PRIVATE-SECTOR DEVELOPERS

Throughout its history, DARPA has often engaged commercial firms to conduct technology and systems development programs. At the heart of this strategy is a principle that is endemic to the agency's entrepreneurial approach. After finding innovative ideas and technological opportunities that address military needs, the next challenge is to find the best people to develop them. If that means contracting with the defense industry, so be it, but for many fields, such as telecommunications, computing, and materials, the commercial sector reigns. DARPA has also kept abreast of the rapid advancements in the commercial technology world and added depth to the agency's knowledge base by hiring private-sector personnel as program managers. One of many examples is Dr. Robert Leheny, now the agency's deputy director. Before he arrived at DARPA in 1987, Leheny was an executive director for Network Technology Research in the Applied Research Laboratory of Bell Communications Research, Inc. He sponsored work in advancing optoelectronic modules, devices that connect optical and electronic systems.

The Commercial Electronics Boom. It was clear to DARPA that the creativity in computing, communications, and information technologies was vested in the commercial electronics industry. It is interesting to note the large number of commercial companies and individuals that were sponsored by DARPA to produce a generation of world-changing products and capabilities. Some of these companies were specifically created to conduct projects for the agency, and an impressive number of them have become recognized names throughout the globe. Sun Microsystems, Apple, Silicon Graphics, Inc., Cisco Systems, Fore, IBM, Compaq, NCR, Cray Research, and others began programs under DARPA's sponsorship to contribute to the creation or improvement of distributive computing and open system architectures.

The hardware side of the information revolution was addressed by DARPA in the same mode, enlisting Hewlett Packard, Intel, Motorola, Analog Devices, Cisco, Bay Networks, Precept, Intel, IBM, and hundreds of other commercial companies to conduct programs in semiconductor modeling, design, and fabrication.

Though at the time no one could predict how ravenous the commercial market would become and how dramatically it would accelerate the advancements in electronics products, it was clear to many that only a market-driven and highly innovative private sector could respond effectively in developing and sustaining the products the military would need. DARPA formed many relationships with the electronics industry from the late 1970s on, and because of the similarities of telecommunication, computing, and robotics needs of the military and civilians, the technologies, and ultimately the products,

developed by DARPA served both sectors. Their impacts have been immense.

The Armor/Anti-Armor Program. Another example of private-sector contributions occurred during the late 1980s and early 1990s. In 1985, a Defense Science Board (DSB) study led by Gen. Don Starry determined that Soviet tanks, with autoloaders, long-range missiles, and 125 mm guns, were both more lethal and more survivable against tanks deployed by the United States. Secretary of Defense Caspar W. Weinberger stated that, "Not only are we behind, but we are falling further behind at an alarming rate. The problem is viewed as serious, approaching one of national urgency." The DSB felt that this was a failure to seek contributions from industry, defense and commercial alike. The solution proposed was to initiate a program at DARPA, under Dr. Harry Fair and then Dr. James Richardson, to bring industry expertise to bear on combat lethality and protection. Although many defense companies participated, the Armor/Anti-Armor program involved numerous private-sector firms, such as Dupont, Alcoa, Lanxide, Foster Miller, GTE, and Honeywell in a seven-year program that transitioned armor and protection system, chemical energy warhead, and kinetic energy penetrator technologies to the Army and Marine Corps. The program was terminated in 1993 when the Cold War ended and concerns about Soviet tanks and anti-armor diminished, but contributions from the Armor/Anti-Armor efforts continue to make a difference.

MAKING THE STRATEGIES WORK: LEGAL AND PROGRAM MANAGEMENT ACTIONS

The principal difficulties in pursuing either of these strategies lay in attracting and working with commercial partners while adhering to the Federal Acquisition Regulations (FAR), a mountain of documents that dictate (or sometimes guide) relationships between the government and its contractors. Another set of problems concerned designing and conducting programs that provided motivations for both government and business. This was particularly true in dual-use technology development. Commercial technology firms naturally had their eyes on profit (larger than the 6 percent variety allowed in normal military contracting), while the DoD tended to be suspicious of such goals and found it difficult to accommodate them in contract mechanisms. For instance, questions of who retained intellectual property rights posed immense quandaries.

Innovations in both contracting and program management approaches were required to establish creative alliances between DARPA and the commercial sector. These changes worked despite widespread private-sector skepticism about working for the government.

CUSTOMER PARTICIPATION AND FEEDBACK DURING DEVELOPMENT

A "build it and they will come" strategy is risky without sufficient input from the customer. In the commercial world this input is often difficult to obtain. Techniques such as market analysis and shelf testing are quite expensive and can still be misleading. But the stakes involved in introducing a new product are too high to skimp on this important step. In military development, satisfying the user is just as crucial. DARPA has worked hard to find ways to bring the military customer into their programs and the agency's contractors and industrial partners reap a huge benefit from the results. Commonly, the agency's products are tested by the military under realistic operational conditions while the development program is still under way. DARPA program managers and contractors often live with military units while this testing is being conducted, yielding a direct feedback on which features of their technologies or systems fail to impress, which provide exactly the right utility, and which must be redesigned or optimized. Perhaps as important, the military sometimes discovers new ways to employ the products that the developer never considered. Cycles of this sort of test-redesign-retest have been built into schedules for programs such as Command Post of the Future, Heterogeneous Urban Reconnaissance Team, and the Tactical Ground Reporting (TIGR) system, yielding optimum solutions in record times. The value of these remarkable interactions cannot be overstated and many of DARPA's commercial participants have wished that these customer insights were more available in the private marketplace.

CONTRACTING

Federal regulations and processes often thwarted normal private-sector business operations and goals. Government contractors tailored their business practices to operate under the FAR in ways that often limited profits, reduced innovation, and demanded arcane contracting and accounting procedures – circumstances under which commercial firms could not survive. Government contracting regulations were originally conceived to impose a high degree of control on production and procurement. But they were also applied to contracting and managing technology development programs directed at creating new ideas and understanding. Unfortunately, these contracting vehicles were generally too controlling and difficult to maintain – anathema to commercial R&D firms designed to avoid inefficiency and waste.

Partly in response to this situation, DARPA added a general counsel to its staff. The counsel, Richard Dunn, described the difficulties succinctly:

> During the period from 1958 to 1988 the regulatory nature of federal contracting evolved. The system was slower, less responsive and more complicated in 1988 than it had been in 1958. Government imposed business practices, accounting standards, [and] intellectual property rules made government contractors uncompetitive with firms engaged in commercial business. The nature of the government market changed dramatically during the same period. The military had once been by far the biggest customer for jet engines, lasers, computer chips, and other high technology devices. By the 1980s that was no longer the case. A specialized defense industry that once existed because it provided high tech products was perpetuated because it operated under a set of rules and regulations incompatible with the business practices of highly competitive, high tech commercial companies. DARPA was confronted with the problem of dealing both with commercial companies that were on the leading edge of technology and a different set of companies that did nearly all their business with the military.

The new general counsel produced a series of four "special authorities" needed to address some of the problems described

above. One of the special authorities allowed the use of "other transactions," or OTs. Another enabled prototype projects outside the normal procurement statutes and regulations. Two other special authorities provided for more flexible hiring mechanisms and incentive prize competitions (such as the DARPA Grand Challenge).

In 1989, the OT special authorities were approved by Congress. OTs were not subject to most procurement statutes or regulations, nor to the Bayh-Dole Act governing allocation of patent rights under contracts and grants. Most important, OTs allowed negotiation of an agreement based on mutual consent and the interests of the parties almost unconstrained by regulations on intellectual property, cost-sharing, and so on. So negotiations now revolved around what the sponsor and contractor wanted to accomplish, not simply how they could satisfy the rules. For example, these special contracts made it possible to tailor program goals that could attract funding from both government and private-sector participants. The first OT was negotiated and used in 1990. Early OTs served as proving grounds for the TRP, where they ensured that all parties could pursue their mutually acceptable program goals, set responsibilities among participants, and precisely articulate the products to be delivered.

PROGRAM MANAGEMENT

DARPA's experience with the electronics industry since the early 1970s provided an understanding of how to work with commercial industry. That understanding was furthered through the TRP. Under the latter program, relationships were defined and formalized. Some of this was codified in the TRP budget language by Congress, but much of it evolved out of the direct experience of DARPA's program managers.

Reaching the Players. One of DARPA's strengths has been its ability to find people and organizations best suited to conduct successful and innovative development programs in a given technology area. Part of this comes from the DARPA program managers' collective deep understanding of that area, but much can be attributed to the agency's outreach efforts, especially to the commercial sector. For example, in the TRP, open sessions on each technology area planned for the next proposal solicitation were held in locations across the United States. All interested parties were invited to attend and speak, either in open sessions or to a DARPA program manager.

Consortia. Congress mandated that each TRP effort be organized as a consortium. All proposals were required to include two or more eligible firms and/or a nonprofit research corporation. Each consortium usually combined elements of the defense and commercial sectors, academia, and nonprofit organizations. This helped to address both the commercial and military markets.

Program Negotiations. Agreements were hammered out, not only between the proposing consortium and DARPA, but also among the members of the consortium itself. The government/consortia negotiations were conducted by the DARPA program manager, with the help of DARPA's general counsel and its contracting officers. The OT authority was generally used.

Cost-share. One of the most important mechanisms used in the TRP, cost-share focused each consortium on achieving the goals of their program because each was paying at least half of the costs. It is axiomatic that industry's cost-share reduced the cost of the development project for the government. What was not so predictable is that 77 percent of the responding companies polled believed that cost-sharing benefited them.

THE FUTURE OF COMMERCIAL INVOLVEMENT AT DARPA

It is of great importance to note that the contracting and program management concepts discussed above have slowly gained acceptance well beyond DARPA. Many major and minor program thrust areas in every military service have saved dollars and time through the adoption of these approaches.

In view of government and private industry R&D funding trends and the rising need in the DoD for essentially commercial technologies, there is little doubt that the agency will continue to seek involvement with the private sector. What form that involvement will take and whether it will be as creatively and successfully handled as it has been in the past is yet to be revealed – but it is a good bet that it will be.