TECHNOLOGY TRANSFER at DARPA

THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY: A Diagnostic Analysis

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FOREWARD

This study has been directed toward the analysis and improvement of technology transfer efforts at DARPA. Except in the final chapter which deals with recommendations, we have tried to avoid subjective judgment, grounding the analysis in statements made by DARPA staff members and other relevant experts.

The report recognizes DARPA's significant contributions to military R&D, but also notes weaknesses. While DARPA's mission and role within the Deparment of Defense is unique, we observed a number of functions which could be generalized to other government R&D support agencies. From this perspective, the results and recommendations can be viewed as generic to all technology transfer efforts operating within the public domain.

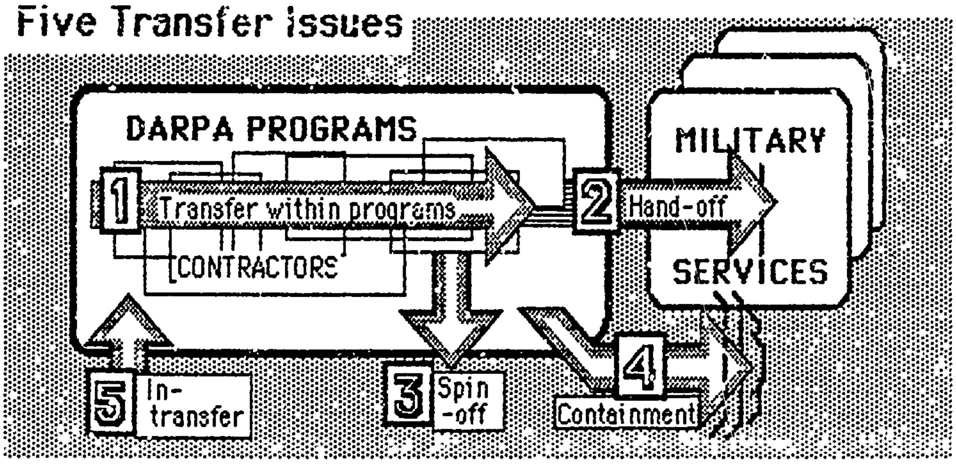
For those interested in an overview of the report and its major implications, Chapters 1 and 7 should be sufficient. For those who are more interested in an in-depth understanding of DARPA's operating philosophy and strategy, Chapter 2 is most relevant. Chapters 3 through 6 explore the four major transfer issues: 1) hand-off to the military, 2) spin-off to the private sector, 3) containment of unwanted transfer or leakage to potential adversaries, and 4) transfer of new ideas and technology *into* DARPA programs.

Overview and Recommendations

Five technology transfer issues have been identified as relevant to the DARPA mission:

[1] transfer within programs ['*intra-transfer*'],
[2] transfer to military users ['*hand-off*'],
[3] transfer to non-military users ['*spin-off*'],
[4] undesired transfer or leakage ['*knowledge containment*'],
and
[5] transfer into DARPA from other sources [' *in-transfer*'].

Five Transfer Issues



1. **Transfer within Programs:**

Intra-program transfer describes what DARPA program managers do on a day-to-day basis and typically involves seven strategies:

* enlisting the best talent,
* encouraging social interaction,
* encouraging inter-institutional linkages,
* providing adequate and sustained fiscal support,
* concern for downstream applications,
* promoting creativity
* supporting innovations which strengthen the R&D system.

These elements combine in the hands of capable program managers to produce timely transitions from basic to applied research, from applied research to development, and from development to demonstration of use. The critical task of management is to identify the points of *transition* where DARPA interventions are required, e.g. to expand a program, to redirect, to link universities and private firms, to bring in the military, to impose security classification, to transfer to another support agency or to terminate. However, documentation of programs and projects is minimal, and there are no consistent policies or procedures for report distribution and program review. Duty tours of program managers are typically short. The result is a weak institutional memory. Reasons for past successes and failures are not examined, and therefore opportunities for progressive increases in effectiveness are missed.

(2) Transfer to the Military:

DARPA employs a number of strategems to facilitate transfer of developed technologies to the services, but they have not always worked smoothly, and in some cases there have been serious disputes between DARPA and the services on the value of DARPA-developed items. The frequency of failure, the persistence of conflict, and the consistency of certain criticisms of DARPA's approach suggest that there is considerable room for improvement and probably that the entire process should be overhauled. Several changes might improve transfer to the military: a more comprehensive briefing process, a better mechanism to get service inputs to project selection, improved circulation of documents, more attention to recruitment of active duty military personnel, and the appointment of a special facilitator to oversee the hand-off process.

3. Domestic Spin-off:

Spin-off to private sector has received minimal attention by DARPA. Nevertheless agency-sponsored developments have sometimes diffused widely and had considerable effect on the domestic economy particularly in the computer field. Such spin-off has direct military value when the armed services later buy commercial products that embody that technology. Certain military applications only become apparent through private sector diffusion and development. Inattention to spin-off may also lead the Congress, the Executive Branch and the general public to a gross undervaluing of DARPA's over-all contribution to national strength.

4. Technical Knowledge Containment:

All DARPA's contractors share a great concern for the security issue, but few if any are able to propose viable countermeasures. There is a general fear that new restrictions on communication within the DARPA network would reduce creativity and productivity and might thus have a net negative effect on the Nation's standing as a technology leader. However, the agency could [1] move to establish a more explicit set of policies for containment, [2] begin to gather some sample data on the extent of foreign contacts and other potential sources of leakage, and

[3] convene special meetings to increase contractor sensitivity to containment issues.

5. Transfer into DARPA from Other Sources:

DARPA has no reliable process for acquiring new ideas from sources outside the DARPA contractor pool. Better intelligence is needed on what is going on both in the U.S. and in foreign countries including the Soviet Bloc. Some system should be developed to provide a reliable early warning of scientific and technological developments, particularly in fields outside the current project portfolio of the agency. "No more surprises" was the original charge to DARPA in 1958. It remains the most valid rationale for the continuance of this agency in 1985; to meet that goal, it must do more than follow through on current program priorities. It must reach out aggressively for new technologies wherever they may be.

Recommendations

Five specific recommendations are made for early action.

- Appoint a full time *tech transfer facilitator* to oversee the transfer of mature technology into military use, to increase DARPA awareness of military needs and parallel R&D efforts, and to promote improved linkage generally between DARPA and the services.

- Develop a state-of-the-art *on-line retrieval system* for tracking all programs and projects from conception through final reporting.

- Begin a special process of *Reporting* on critical program transition points together with a listing of outcomes at each stage. At such points special consideration should be given to: diffusion of findings to other DoD units, procurement changes, and security controls.

- Convene a panel to draft a *DARPA policy on access to unclassified technical knowledge* and to initiate a sample data collection effort.

- Initiate a systematic periodic *search for new technologies* in the form of an annual competition to identify and evaluate technologies in very early stages of development.

Chapter One: BACKGPOUND

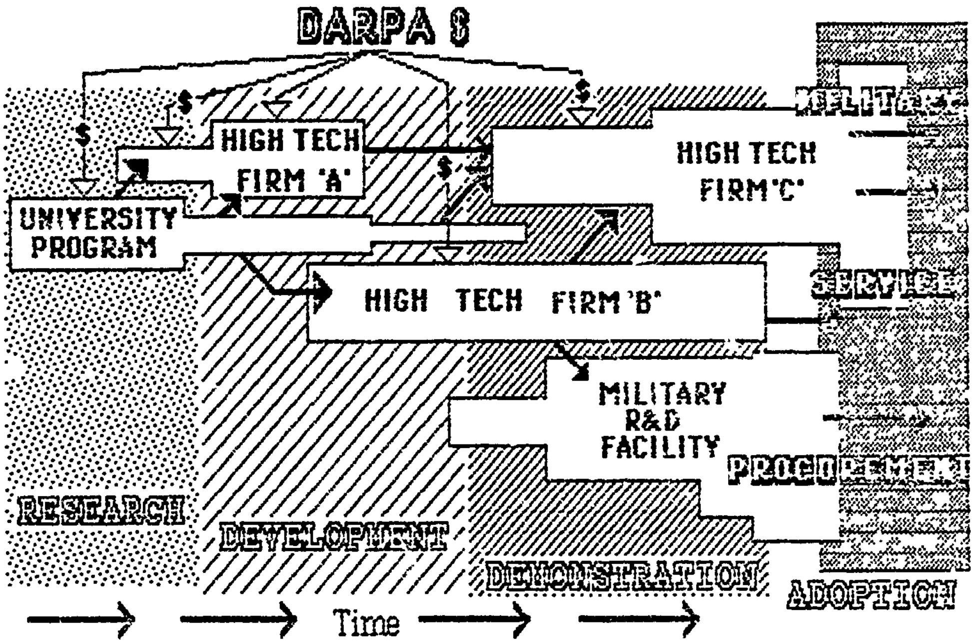
A. Introduction

The United States and its allies have been engaged in an unremitting struggle for military supremacy with the Soviet Union for the last forty years. The competitive struggle is not seen by most of us as one of our own making but rather one that has been thrust upon us. At the end of World War II, the United States and the Soviet Union were by far the strongest military powers on Earth and have remained so throughout the intervening years. However, their relative power and relative inclination to use power has never been symmetrical. The United States and its allies quickly demobilized their conventional forces at the end of the war, whereas the Soviet Union did not. Although a partial rebuilding of such forces soon occurred under NATO, the United States has consistently followed a strategy which relies on *superior technology* as a counterforce sufficient to inhibit the use of conventional forces by the Soviets.

At least two major events since the end of the Second World War have shaken Western belief in such a strategy. The first was the development and test of a nuclear device by the Soviets in the early 1950's, and the second was their successful launch of an orbital satellite in 1957, followed rapidly by a series of launches of surprisingly heavy and sophisticated payloads. These two events, above all others, convinced the Western powers that they had no monopoly over advanced technology. Even with a weak economy and a barely adequate standard of living, the Soviets were able to mass resources in certain selected areas so as to catch up to and even surpass the West in strategically critical areas where the United States had previously assumed superiority.

It was that concern which led to the founding of the Defense Advanced Research Projects Agency (DARPA) in 1958. This new agency was established to do whatever was necessary to insure a U.S. edge in strategically critical technologies, no matter what they might be. It was then and remains today the lead Agency in the Department of Defense (DoD) for the sponsorship of basic and advanced research. Its mission is to promote research and development in areas that crosscut the needs of the military services. While it has played a key role in supporting pioneering research in ordnance and aerospace technology, perhaps its most significant contribution has been its "pivotal role in cultivating some of the most important fields in computer science and in pioneering many of the computer-related technologies that now permeate our society." (Davis, 1985). It allocates and manages much of its R&D support as long term commitments. Figure 1 suggests the over-all process.

Figure 1: DARPA's Role in Research and Development



Programs begin with conceptual and fundamental studies and then progress toward the development of new processes and techniques. If all goes well, development work leads to a demonstration of the practical value and military applicability of the technology. Each sequence may take a number of years to complete and may involve contracts with universities, government laboratories, and private firms. Usually a demonstration involves cooperation with one or another of the Armed Services along the way, but this is not always the case. The dark arrows in the figure suggest the flow of technical knowledge among contractors as development occurs. All these flows are, of course, technology transfers. DARPA's role is to make sure that development happens: this means defining the task, finding the right contractors to perform parts of the task, and making sure that the right connections are made among tasks and among contractors.

Figure 2: The Program Portfolio: A Schematic Overview

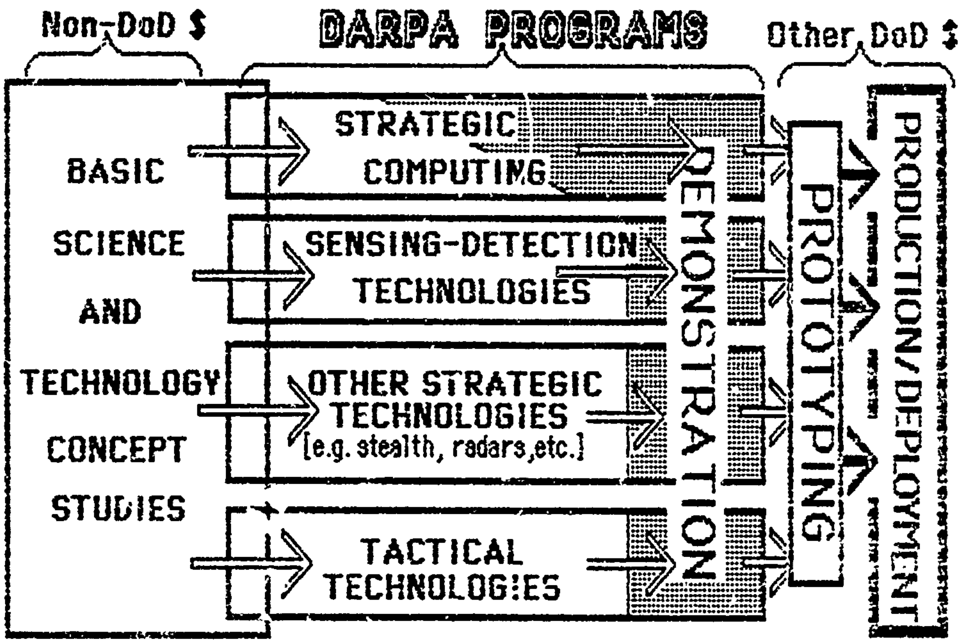


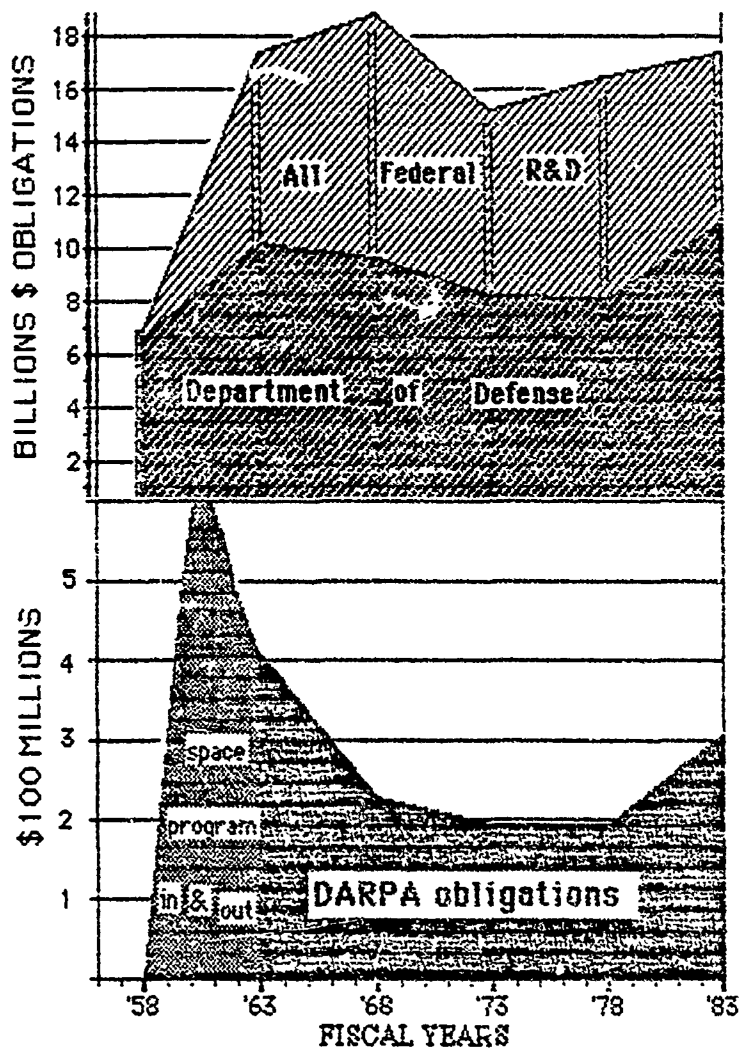
Figure 2 provides an abstracted schematic representation of the DARPA program portfolio. Over the years emphases change and new programs emerge as old ones are phased out. Although there is no attempt at an exhaustive coverage of scientific or technical areas, a large portion of DARPA's budget is earmarked for basic studies generally conducted in university settings. Since 1958 major areas of exploration have included: (a) space science and technologies such as the design of booster rockets, satellite tracking and observation/navigation satellites; (b) ballistic missile defense; (c) strategic technologies such as advanced lasers, cruise missiles and STEALTH technologies; (d) nuclear test verification techniques; (e) tactical technologies such as infrared nightscopes, drone aircraft, tactical radars and electromagnetic force launchers; and (f) studies in basic science, e.g. ionospheric measurements, particle beam research, metal matrix composites, laser holography and biotechnology (see DARPA, 1983a, for a more complete listing of Agency programs). Overarching this impressive but eclectic array is a guiding ethos which drives the Agency to seek out and support emerging technologies that appear to have a good chance of improving the U.S. military capability or strategic posture. DARPA also seeks opportunities for programs that will feed one another synergistically. Thus, throughout its history, it has supported advanced work on materials, on various sensing technologies like vision systems and radar, and on all aspects of computer technology. The figure also illustrates an important but unclear line of demarcation between DARPA's domain and the domains of non-military basic research on the one hand and the extensive R&D programs supported by the military services and other Defense agencies on the other.

Over the years DARPA has generally maintained a low profile in the expectation that the major technical advances which it has supported will speak for themselves (Barber Associates,1975). However, the announced start of a new ten year plan to develop a "strategic" computing capability may signal a change in the Agency's modus operandi and its profile (DARPA, 1983b). The plans for this "Strategic Computing Initiative" assume very rapid and continuous advances in computing speed, software sophistication and performance, and input/output capabilities. It also assumes that a great number of contractors will be able to link effectively, so that advances are shared quickly and knowledge transferred in synergistic fashion. With so much hanging on the transfer process in this ambitious program, it is clearly important and timely to consider how the transfer of technology has taken place in the past and to evaluate whether or not the same process will be adequate in the future. A better understanding of the transfer process is the first step toward improving transfer. An improved transfer process would not only serve the Strategic Computing Initiative (SCI), but could also advance the competitive posture of the computer and semi-conductor industries in United States vis a vis foreign competitors.

B. Some History

The founding of DARPA in 1958 was a response to Sputnik, the perceived gap in strategic missiles and other areas of technology associated with our national security. It was part of a larger federal commitment to expand the national science and engineering capability. Figure 3 illustrates the dramatic federal R&D budget increase from under $5 billion in 1959 to over $13 billion in 1964 (NSF, 1984).

Figure 3: Federal R&D Obligations: 1958-1983
[in adjusted 1972 dollars]



DARPA was a particular beneficiary of both White House and DoD concern with closing the missile gap. However, after much of its space research program was transferred to NASA in 1959, its proportional share of actual expenditures on R&D by DoD has never been large. Figure 4 suggests that DARPA's budgetary history generally reflects the ups and downs of DoD funding which in turn reflects the perceived challenge by the Soviet Union to our national security as well as the public's view of the value of publicly funded R&D (Barber Associates, 1975, I-5).

In its early years, there was some confusion regarding the true mission of the Agency. There were three conceptions which sometimes worked together but at other times were in conflict. One was to provide an R&D base which served the Office of the Secretary of Defense explicitly and was independent of any of the Services. A second was that the Agency was to be the lead supporter of the most advanced and generic technologies. The third was that it was to be a special R&D unit which could act quickly and flexibly in response to new circumstances and crises, serving the special needs of the *White House*. The history of the Agency can be told in terms of the interplay among these conceptions over the years.

The first mission concept, that it has a superordinate research function in DoD, has never disappeared but has been a source of continuous friction with the military services. DARPA has always done some research which directly parallels and perhaps competes with R&D programs of one or another of the Services. Sometimes this research is seen as of higher quality [e.g. ABM research in the mid 1960's versus parallel Army R&D with which it was subsequently merged], sometimes as irrelevant, redundant and wasteful [e.g. the forward swept wing concept of the 1980's as viewed by many in the Air Force]. However, DARPA does not see itself as competing head-to-head with the Services for R&D funds and its budget has always been small relative to total defense R&D (see Figure 3). Furthermore, DARPA has never undertaken to either coordinate or even monitor what is going on in defense R&D on a Department-wide basis, and it has neither the capability, inclination, nor authority to do any such thing. Nevertheless, the *potential* of performing such a role remains as long as the Agency exists, and the Services are edgy about that possibility.

The second conception, that DARPA should be the leader in basic research and advanced development, was not very clearly articulated in the early years but has gradually gained salience. This is the conception that the Services feel most comfortable with. It began to emerge in 1961 with the appointment of Dr. Jack P. Ruina as Director. Ruina had been Assistant Director for Air Defense in DDR&E but before that he was a university professor. Ruina put special emphasis on the "Interdisciplinary Laboratories" program (IDL), based at universities, and began to recruit highly qualified scientists to fill key Agency positions, giving them university-like autonomy to run programs in their own areas of expertise. This is a pattern that has generally held to the present time, but again not without controversy. The tension here turns on questions of relevance and urgency. IDL-type programs arguably build a national capacity in a technical area but they do not necessarily produce results in a timely fashion. New programs in basic R&D have little prospect of reaping visible pay-offs within the short tenure of any one director or program manager. Nevertheless the cumulative achievements of some of these programs which have been allowed to develop for a decade or more have been substantial and impressive, building the base of credibility that is needed for DARPA's long term survival. Programs in the computer field are usually cited in this regard.

The third conception, that DARPA be a special rapid response science unit serving the president on national security issues, was prominent in the mid 1960's as the Vietnam War gathered momentum. For some years DARPA actually had field units in Vietnam and Thailand to conduct a wide range of projects related to counterinsurgency efforts. Many of these projects [under the program acronym "AGILE"] included social scientists, the first and only significant use of any of these specialties in the history of the Agency. All were oriented toward very rapid application. All were controversial, especially with the Services, but also later with the Congress. After a period of ascendancy where AGILE reached nearly one third of the total DARPA budget, it went into decline in the later 1960's and most vestiges had disappeared by the early 1970's. AGILE left scars which are still visible. It was largely responsible for the eclipse of the rapid response conception and the subsequent determination of the agency to maintain a low profile.

DARPA's success as a sponsor of R&D can partly be attributed to the consistently high professional calibre of its directors and its staff over 25 years. Its reputation for flexibility and responsiveness to new developments is often attributed to the fact that the Agency is small. It is able to adapt quickly to new developments in its areas of interest, and it maintains a tradition of non-bureaucratic management practices. Figure 4 charts the history of DARPA directors and demonstrates that their tenures were usually brief. While each director brought with him his own priorities, there was a consistent theme: support of high quality, long-term research which has clear downstream military relevance. That theme has persisted in spite of the turnover of directors and despite the turbulence and controversy which surrounded its programs in the late 1960's and early 1970's.

While the early 60's can easily be viewed as DARPA's golden age, the late 60's and early 70's might be described as its "coming of age". Under the directorship of Drs. Rechtin [1967-70] and Lukasik [1970-75], DARPA moved toward closer linkage with specific Service and DDR&E requirements. They emphasized applied research particularly in the information processing, human resources, and materials areas (Barber Report, 1975, I-12). They also put more emphasis upon problem orientation and transfer to the Services, a move which helped overcome an earlier animosity and suspicion among members of the military. While the Agency did not succeed in answering all of its critics among the Services (as noted in this document), it did move a substantial distance closer to meeting the needs of its designated clients. This "maturity" reflected a fusion of the inter-service R&D and the basic development concepts discussed above.

In the fall of 1983, DARPA commited an initial $600 million to a ten year plan for strengthening computing technology in the U.S. with the hope that it would yield dramatic advances in microelectronics, computer architecture and artificial intelligence (Stefik, 1984). The program is designed to support the development of a broad array of technologies that promise to create more intelligent computers. The ultimate objective of SCI is two-fold: to build "collaborative" machine intelligence systems to assist human operators and to create autonomous systems able to function without human intervention.

SCI may be a milestone in DARPA's history of special interest in a number of ways. First of all it takes advantage of already existing technological breakthroughs and builds directly on what has been one of DARPA's longest and strongest program areas: information processing technology. However, it represents a new departure in being strongly oriented to some specific and ambitious outcomes of obvious practical significance. They are also outcomes which will have a lot of 'splash' and will likely lead to an elevated DARPA profile. Finally, the SCI appears to represent a new approach to program management, with more self-conscious and detailed planning and more concern for technology transfers both within program and to the Services. The birth of SCI therefore represents a propitious moment for a re-examination of DARPA's approach to management of programs with specific reference to the transfer issue.

C. The George Mason University Project

In the fall of 1984 the Technology Transfer Study Center at George Mason University undertook the development of a technology transfer model for consideration by DARPA in support of its long term commitment to the Strategic Computing Initiative. A three pronged approach was undertaken for the purpose of evaluting DARPA's present strategies for technology transfer and for the strengthening of those strategies where needed.

STEP 1 called for the gathering of information on DARPA goals and programs as background for the model building effort. Two person interview teams met with key DARPA officials over a two month period to obtain information on the Agency's approach to SCI and its various strategies for carrying out that mission. Ten top level and intermediate level program managers were asked to identify key actors in SCI, critical links between universities and technical firms, and specific mechanisms employed by DARPA for the transfer of technology, e.g. conferences periodicals, data bases. Barriers and facilitative strategies for overcoming these barriers were explored. In addition available documents, reports, and diagrams were obtained as supporting evidence for observations made. Transcribed interview notes were reviewed for accuracy and completeness by all respondents and subsequently analyzed for use in the preparation of this report.

STEP 2 probed the perspective of DARPA's principle clients, the three military services. Information on the goals, transfer timetable and linkage problems were collected and explored by means of staff interviews with seventeen top and middle ranking military personnel in each of the three Services.

Interviews with industry and university based scientists and administrators were also conducted by means of a cross-sectional sample of organizations with whom DARPA is currently or has been actively associated. The technology transfer process was studied by identifying critical interface issues and how DARPA meets its obligations and commitments. Data on key events and actors together with support networks and level of financial support were gathered with the intent of judging how technology was brought from the research stage to the demonstration and hand-off stages. Timetables, reports, and other available documents were scrutinized as backup evidence supporting the interview results. A cross section of university- and industry-based people were interviewed around the country by two person staff teams. Twenty-one interviews were conducted over a four month timeframe during the winter and early spring of 1985. When gaps and ambiguities were found in our field notes, return visits and follow-up telephone calls were arranged to resolve them.

The draft document was circulated among reviewers with extensive DARPA experience. A second draft was presented to an external project review panel of engineers and social scientists with strong backgrounds in technology transfer and transfer research. A third draft was prepared based on their comments, followed by the current fourth draft which incorporates additional material from our case study research and our analysis of the Barber Associates report on the 1958-75 period.

D. Five Types of Transfer

DARPA's small cadre of program managers are responsible for overseeing the entire process of knowledge transformation and transfer from basic science to the demonstration of a direct military application. This may include defining the need as well as the ultimate benefit, putting together the pieces, determining and designating who should carry out the work, and then providing them with the requisite support. Program managers then work in close collaboration with contractors to establish a schedule for the accomplishment of various subtasks, integrating these different subtasks, and monitoring the entire effort. Because the sequence necessarily involves both the transformation of knowledge and the transfer of that knowledge from one location to another, it can be described as a sequence of knowledge or technology "transfers". Each sequence of projects or each program in its totality can also be described as a "technology transfer" process. Indeed, "transfer" is one way to describe most of what program managers do. An essential part of their task is the management of the flow of technology from one form to another, from one setting to another and from one context and application to another.

Five types of technology transfer have been identified as having relevance to DARPA. These are:

[1] " *intra-program transfer*";
[2] " *hand-off*" to the military services;
[3] " *spin-off*" to other users in the public and private sectors;
[4] *"containment"* of transfer to undesired users; and
[5] *"in-transfer"* of technology to DARPA programs from other knowledge sources.

As noted above intra-program transfer is one way of describing what DARPA staff do on a day-to-day basis. It involves the planning and execution of the project sequences referred to earlier. There is a special drive in DARPA to plan these sequences and their transitions so that technical advances are made as rapidly as possible and so that the highest quality of advances are made. In the first section below we will describe what we see as the essential features of this process under what we call DARPA's "modus operandi".

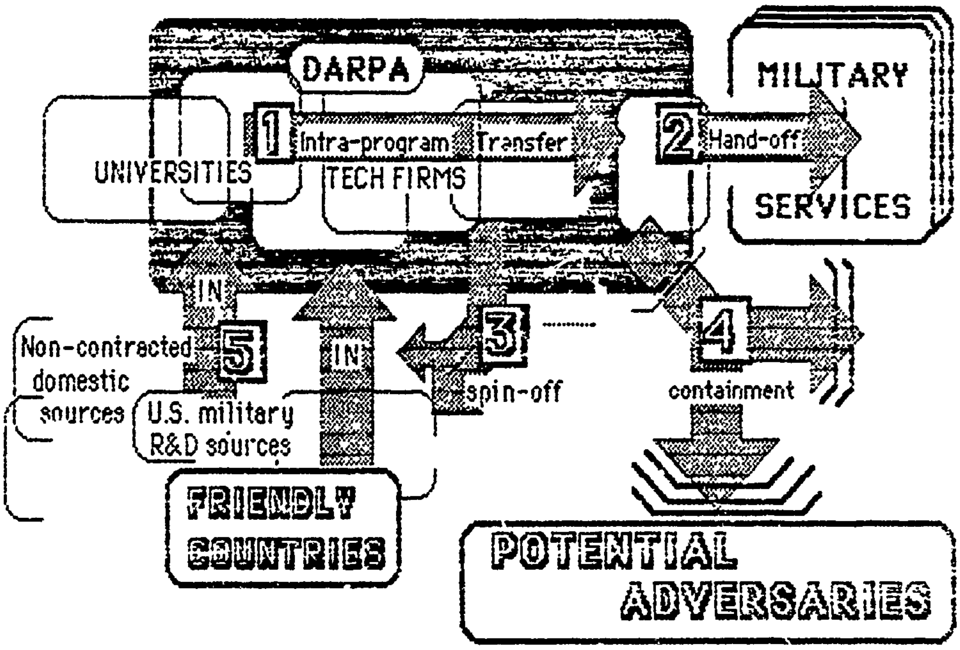
DARPA also must play an important but constrained role in the actual transfer or diffusion of developed technology into military service applications: when the demonstration has been completed successfully, DARPA's task is technically done, and its resources can then turned to new projects and other upstream concerns. There is a presumption that if the demonstration is done well, the relevant military service can then make informed judgements based on its own needs and the known capabilities of the various firms involved in development. It is not clear that this inter-agency *hand-off* always works as well as it might, but DARPA does employ a number of social and managerial strategems to facilitate the hand-off.

The third area of possible transfer activity is the *spin-off* of technology from DARPA-supported efforts into private sector or non-military applications. Most DARPA staff are aware that spin-offs happen and are sometimes substantial (e.g. it was noted by one informant that at least two key innovations in the very successful Apple Macintosh microcomputer were actually directly the result of earlier DARPA projects.) . However, to date there has been minimal attention paid to such spin-offs and no resources have gone either into their documentation or promotion (in contrast, for example, to NASA's promotion of spin-offs through its Technology Utilization Program).

The fourth area of high potential concern to DARPA where there has been only limited explicit activity to date is the international transfer of DARPA-supported technology. Here, of course, the primary concern is more one of *containment* of knowledge rather than its dissemination. DARPA's management philosophy (to be discussed more fully below) generally encourages vigorous and many-channeled exploration of evolving technical possibilities among the leading scientists and engineers in the Western world. This is particularly the case in the earlier stages of a sequence. At least in part to maintain such an atmosphere of open discussion and friendly competition, DARPA does not seek security classification for much of its work. This policy inevitably results in some leakage of important technical breakthroughs. Friendly countries can acquire such knowledge directly through the participation of their scientists in DARPA programs and through the many graduate students who are allowed to be directly involved in DARPA projects. Additionally, all countries including potential adversaries can acquire DARPA-developed technology through conventional scientific and academic channels, including the published journal literature and open professional meetings here and abroad. Some DARPA officials see this knowledge containment problem as an important and growing concern, but it has not yet been subjected to specific study so that the amount of such transfer and the relative advantage or disadvantage of current policy for long term security are both unknowns [see the working paper by Havelock, 1985: "*Knowledge Containment* for further exploration of this area].

The fifth type of transfer which is important to DARPA and which <u>does</u> get some attention from staff is what we have chosen to call *in-transfer*, i.e. the acquisition of knowledge from other sources to enhance exisitng DARPA programs or to intiate new ones. DARPA staff keep track of new developments particularly in the engineering sciences and are able to modify programs or introduce new ones based on evolving awareness of the "state-of-the-art". There are at least four types of in-transfer of relevance to DARPA and some receive much more attention than others. Two types take place within the DARPA institutional network: these are (1) cross-project fertilization for *program enhancement* and (2) new program *bud off* from other on-going or terminating programs. Both these types of in-transfer result from the fact that projects evolve in diverse and unanticipated directions; some lead to new application possibilities which can enhance other on-going programs; other developments may justify whole new endeavors with new objectives. DARPA seems to be always alert to such possibilities and to be effective in exploiting them. The two other types of in-transfer are from sources outside the DARPA institutional network, i.e. (3) from other centers of research and development activity inside the United States but not currently affiliated with DARPA, and (4) from other countries including potential adversaries. DARPA staff are fairly active in an informal sense in seeking out important developments from these external sources, but there is a widespread belief that there is not too much to be learned from either since DARPA's own network includes almost all the leading professionals doing the most advanced work in the world. If new domestic centers emerge, DARPA seeks to include them in its own network as soon as possible. Figure 4 attempts to display the different types of technology transfer which have been mentioned above.

Figure 4: Five Types of Transfer



The large rectangle in the upper part of the diagram is intended to represent any one of the DARPA programs including the various contracts that are let to different institutions over a period of time sometimes extending to ten years and longer. The three double arrows within this "program" rectangle are meant to represent the many inter-disciplinary and interinstitutional transfers that must take place to bring a program to fruition in the form of a successful demonstration. Not shown are the many inter-*program* transfers that add so much to the productivity of the collective DARPA enterprise. Similarly, in illustrating hand-off to the military and spin-off to the private sector the figure does not show that such transfers can occur at any phase of development. It can occur from university to university and from firm to firm as well as from firm to government laboratory, etc. Leakage of technology can also occur through any orifice in this very open many-orificed network.

In the following sections we will discuss in more detail how DARPA currently views and manages technology transfer of each of the five types mentioned and represented in Figure 4. We will begin with intra-program transfer because this is the area where DARPA staff have the greatest preoccupation and it is in this area that their unique operating philosophy and strategy is most clearly revealed.

Chapter Two. THE MODUS OPERANDI:
HOW DARPA MANAGES ITS PROJECT PORTFOLIO TO ENHANCE PROGRAMS

A. What a Program Sequence Looks Like

1. Overview of a typical sequence

Although it is probably difficult to pinpoint where any one program begins, it is likely to start with a single investigator who is exploring a new concept without DARPA funding and perhaps initially without DARPA awareness. DARPA interest begins with mention of the person or his/her investigation or even merely their domain of interest in some DARPA meeting. In the past DARPA's first direct involvement was likely to consist of a sole-source contract to the institution of that individual, usually but not necessarily a university, to support the development of that idea. If the idea appeared to be leading in promising directions (as determined by DARPA), funding was likely to be expanded substantially to support a "team" including colleagues and graduate students over a period of three to five years. The general objectives of the "research" will be laid out but deadlines will be flexible and there will be enough leeway in the project for the investigators to explore leads wherever they may take them.

A third stage might begin with the development of a contractual relationship with a high technology company to pursue one of these leads toward some process or technique which has manifest utility. At this stage there is likely to be a collaborative arrangement between the university-based researcher and developers in the company project. The deadlines are still flexible, but the objectives more specific, and the scale of funding is probably larger. What might then be a fourth stage is a full scale demonstration project in which the utility of the evolving technology or perhaps a cluster of technologies is clearly demonstrated. This may well be a very large project and is sometimes awarded under a limited competitive bid. The winning bidder is also likely to have considerable experience in developing prototypes and production models of military hardware and to have long-established relationships as a supplier to one or more of the military services. When this demonstration is well along, it may lead in a number of directions. One may be the development of what might be called a "pre-prototype" of a piece of military hardware in which the applications are obvious and in which cost/benefit parameters of production and use can be explored. Another possible direction is the use of the demonstration activity or setting as a test bed for other programs which are still in earlier stages of development. Especially in the case of strategic computing a demonstrated process may become a facilitator for other projects or programs that are further upstream.

Figure 5: A Typical DARPA Program

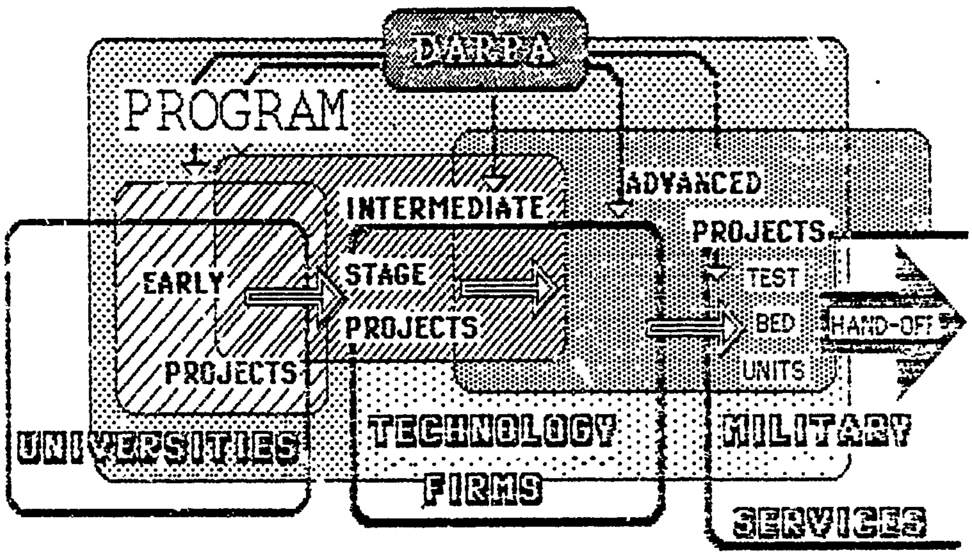


Figure 5 illustrates the general pattern. Although no one program is completely or adequately suggested by this figure, the major elements are more or less constant. In every program there is multi-institutional involvement. In every program earlier work is more in the realm of "research" or "exploration" while later work is more applied, more concretized, more operational, and more obviously related to readily forseeable military needs. In every program there is a need to provide a transition of the technology from institution to institution and probably from one operational context to another.

This *transitioning* is what lies at the heart of the process which DARPA is trying to nurture. It is not merely a matter of moving knowledge from one institution to another. It is likely to call for bringing together people from different disciplines and from different professions with fundamentally different orientations and perhaps values. Those that were involved in the original creative process may have to be enlisted to train others or perhaps to transfer themselves for a time or permanently into new organizational environments which operate under different sets of rules. Technology firms that might otherwise be competitors carefully guarding company secrets are forced to collaborate and share technical information with universities and sometimes with one another. DARPA, of course, exerts power through holding the purse strings, but its role is far more dynamic and central than that suggests. DARPA staff actively force communication through private meetings and frequent visitations. Most DARPA staff are highly competent technically, often hired away for a time from the very projects they have nourished.

Managing computer development programs may present special problems of technology transfer. Progress in this field has been extremely rapid over the last two decades and seems to be expanding at an accelerating pace. Areas of extremely rapid expansion include: [1] the number of universities offering computer science programs; [2] the number of universities claiming to have a strong research capability; [3] the number of sub-specialties within the field; [4] the number and diversity of firms working in the field and having R&D capabilities relevant to computer advances; [5] the amount of private risk capital available for new ventures; [6] the number and diversity of uses of computers in all fields of practice including the military; and [7] the number of people actually using computers in their work.

Along with this great domestic expansion particularly in the last five years has come greatly increased *foreign interest* in computing technology. Friendly foreign countries are increasingly eager to exploit technical advances emanating from U.S. R&D programs including those sponsored by DARPA in order to compete with their products in the U.S. and worldwide computer market. This kind of friendly commercial competition may or may not represent a threat to the strength of the United States in a broad sense, but while it worries many in and out of government, up to now it has *not* been a major concern for DARPA. Indeed, many advanced research projects involve foreign contributors, foreign universities, and foreign high technology companies.

What is of more concern to DARPA is potential leakage of important technical know-how to potential adversaries through the aforementioned friendly countries and through other channels. Because the field is expanding so rapidly in so many respects, it would appear to be a major task merely to keep track of developments. Nevertheless, most DARPA staff interviewed in the winter of 1984-5 remain confident that the agency is on top of developments, is engaged with the top minds, and has a lead in technology over all other countries which can be measured in years. The "*Strategic Computing Initiative*", announced in the fall of 1983 and projected as a ten year effort with $300 million budgeted for the first three years, is seen as a DARPA strategy to promote more rapid development and exploitation of emerging technologies and to thereby extend the technical lead.

As an approach to technology transfer strategic computing works in at least four ways. First of all, the program brings together nearly all computer R&D efforts that DARPA has been pursuing for many years under *one coherent planning scheme*. Although the plan is in some respects opportunistic and ex post facto, it allows very many separate projects to be viewed as parts of one coherent overall new technology thrust. Secondly, by projecting as program outcomes three major demonstrations, each one directly targeted to the needs of one of the military services, strategic computing exerts a persistent and well rationalized *directional influence* toward downstream application and use on all existing projects under this programmatic umbrella, even those which had been undertaken before strategic computing was announced as DARPA policy. Thirdly, strategic computing compels *convergence* of the major developmental streams of computer technology [i.e., artificial intelligence, chip design and fabrication, and architecture]. Fourthly, strategic computing is designed to force *synergistic interaction* among contractors. Many demonstration/applications are intended to serve as test beds or facilitative mechanisms which will be available to many other researchers in many other institutions. This kind of test capability is intended to strengthen many R&D efforts in addition to focussing them on applied concerns. Thus, while each of the demonstrations may lead to prototype hardware [not developed under DARPA auspices or with DARPA funds], it is also intended to lead to further developments and refinements of the entire R&D enterprise, probably including the generation of new projects of a fairly basic nature. This "circle-back" pattern happens frequently in the R&D process, but is rarely so clearly articulated as a policy by an R&D support agency. Nor is this circle-back approach original with the strategic computing program within DARPA. The development of both the ARPANET and the MOSIS which predate strategic computing reflect exactly the same logic.

The patterns described above in general terms can be illustrated in case histories which trace the development of specific technologies from their origins through various institutional connections. During 1985 the George Mason University Technology Transfer Study Center will complete three retrospective case studies tracing DARPA-supported technological developments which predate and made possible their major current thrust in this area, the "strategic computing initiative". These antecedent programs are [1] the development of computer timesharing procedures, [2] the creation of a network to interconnect dissimilar computers [ARPANET], and [3] the development of a system for rapid turnaround in the fabrication of custom-designed integrated circuit silicon microchips [MOSIS].

2. Early, middle, and late stages of a sequence compared

A major distinction within programs should be made between early and late projects. The former are mostly university-based, monitored informally, providing maximum latitude to the principal investigators to pursue whatever leads they feel are promising.

Middle stage projects, in contrast, are most likely to be non-competitive contracts with companies that specialize in high technology development and have a substantial capacity to perform R&D in-house. Their staff have a capability of operating on a colleaguial level with academic counterparts. Frequently they will engage academic researchers as consultants or employees and will send their own professional employees for training and residence on campuses where the prior upstream research was conducted. Typically in the middle stages projects are not classified, but there is an assumption that the companies, themselves, will have a high stake in protecting important developments which will lead to downstream military applications. Project monitoring responsibilities may also shift within DARPA from units responsible for "science" projects to units responsible for "engineering applications".

In later stages projects are often awarded on a competitive basis to a select circle of large technology firms. These firms are almost inevitably also suppliers to the military services. There will be little if any academic involvement remaining, and there will be substantial increase in involvement by one military service or defense-related agency. The "hand-off" transfer issue now comes to the fore, and a number of hand-off mechanisms come into play [as discussed in the next section of this paper]. Most work is now classified and responsibility within DARPA may shift again to a unit with more explicitly military objectives. Turf issues between DARPA, the Services, and other DoD units are also likely to surface at this time. DARPA must walk a fine line between demonstrating the feasibility of a technology and producing what might be seen as a protoype of some new piece of military hardware, the latter being seen by many as outside DARPA's purview. Any time DARPA gets into the business of "metal bending", its role becomes more ambiguous and it is more likely to be viewed with suspicion by the Services.

3. Merging streams

One of the most complex management challenges that DARPA must deal with is the convergence of separate streams of technical development into one. In some ways this is the essence of development: combining separate elements of knowledge to produce something new. But for a contracting-funding agency of the government such as DARPA bringing about such convergence is a most challenging and complex task; the separate streams of development are not merely pieces of knowledge; they are more likely to be complex packages in which the knowledge is tied together with people and institutions and perhaps with vested interests. DARPA employs a number of strategems, usually in combination, to achieve convergence. The chief of these is extensive informal monitoring and retention of overall program planning control within DARPA. Nowhere is the stream-merging process better exemplified than in the strategic computing program now under way.

4. Building inter-disciplinary connections

There is some awareness at DARPA that important discoveries can be made when researchers from different fields are brought together and either encouraged or forced to interact around a common problem. Normally in academic settings such linkages are difficult to arrange and unstable. DARPA tries to foster such inter-disciplinary connections although it is not clear: [a] how important this type of linkage is in DARPA's thinking, [b] how much of it actually goes on, [c] what disciplines are most in need of linkage, [d] how much deliberate planning by DARPA goes into the problem , and [e] what particular DARPA strategies make it happen. However, with regard to the strategic computing program it is evident that different disciplinary efforts will have to be strongly inter-related at the demonstration phase if each of the three demonstration objectives is to be realized.

5. Building inter-university connections

It is also important for DARPA to foster inter-university communication and sometimes collaboration on major projects. There are some factors which make this type of linkage especially difficult and others which make it easy. On the minus side is the penchant of academic researchers to be independent, to pursue their own interests wherever they may lead them regardless of the stipulations of a government contract. This penchant is perhaps more pronounced at the institutions with the highest prestige and among the academics viewed by their colleagues as doing the most outstanding work. These are the very people that DARPA makes a special point of seeking out and supporting. On the other hand, these same people are gregarious and strongly motivated to communicate to colleagues at different institutions about their work. Thus the journal and the professional meeting are time-honored means of realizing inter-institutional linkage. DARPA is particularly supportive of meetings at frequent intervals and often arranges them.

6. Managing the university-industry interface

In some ways the exchange of knowledge from universities to technology firms and vice versa is the most important linkage issue for which DARPA has full responsibility. A number of strategems are employed to strengthen this linkage. The most obvious is contract specifications which more or less force university people and firms to work together. Another is the frequent invitation-only meetings which are always well attended. A third is the surveillance by DARPA staff who make frequent visits and are always technically competent and understanding of what is going on within each institution.

7. Managing inter-company connections: collaboration and competition

Most of the companies which work on DARPA projects have strong proprietary interests to protect. However, this does not appear to loom large as a problem for DARPA in eliciting the appropriate amount of inter-company linkage. There is frequent collaboration through sub-contracts, and there is strong and presumably healthy competition in some areas. For example, the "autonomous land vehicle" project [one of the three major demonstrations specified under the Strategic Computing Initiative] is intended to encourage strong competition among both universities and technical firms in giving multiple remote access to the test bed vehicle and range.

8. Managing the industry-military interface (test beds, etc.)

Another important linkage task which must be performed well by DARPA is the management of the industry-military interface such that companies come to better understand and respond to military needs and military services come to better understand the potential of the technology which is being developed. This is both an intra-program transfer issue [for middle stages of development] and a hand-off issue [for later stages of development], but since the mechanisms are essentially the same, they will be discussed more fully in the next section under "hand-off".

B. Major Tenets of DARPA's Operating Philosophy

When we look across the DARPA portfolio , a pattern of management emerges which is rather unique either for a federal agency or any R&D funding agency or R&D facility. The essential DARPA modus operandi has at least seven outstanding features: [1] enlisting the best talent, [2] encouraging social interaction, [3] encouraging inter-institutional linkages, [4] providing relatively bountiful support, [5] inserting a continuing concern for movement toward downstream applications, [6] promoting creativity, and [7] supporting capacity-building innovations with circle-back potential.

1. Enlisting the best talent

From its earliest days DARPA has worked most intensively with a small group of universities which would be on most lists of the academic elite of the United States, certainly in the engineering sciences. In computer R&D these have always included MIT, Stanford, the University of California at Berkeley, and Carnegie-Mellon. It may be accidental that these institutions figure so prominently over the years as recipients of DARPA support but it is clearly the case that DARPA seeks out "the best and the brightest" in academia or wherever they are to do its work or to support the progress of their work. It is even willing to go outside the United States on occasion where the top talent appears to reside there.

It applies the same standards when it goes into the private sector, typically soliciting firms with high capacity, and strong track records [sometimes even where these are not U.S. firms]. It makes use of competitive bidding where it knows that several institutions can produce at a high standard and shuns that process when it clearly perceives a superior capability at one institution. It is aware that many elite academic institutions [e.g. Cal Tech] shun the competitive bidding process altogether.

DARPA is able to maintain high standards and appeal to scientific elites in part because of the quality of its own staff. Unfettered by many of the constraints of typical bureaucrats and building on its reputation as the hub of an elite R&D network, DARPA is able to attract personnel who are as technically competent and as highly respected as their colleagues in universities and private firms. Indeed, most come from universities and technology firms and return to those institutions after a period of service of three to five years [tenure in DARPA is among the lowest of any federal agency].

2. Encouraging social interaction

DARPA is constantly working at building and maintaining an elite fraternity among its institutions, not merely by recruiting them and giving them support but also by encouraging and forcing frequent interactions among them. Private review meetings are held once or twice per year for all the investigators working in a given area and attendance by principal investigators at such meetings is reported to be near 100%.

DARPA staff also make frequent visitations to all their projects and have reasonably generous travel budgets to allow them to do so. Because DARPA staff usually have substantive expertise and strong technical interest in the projects they are monitoring, such visitations are rarely pro forma and typically involve a good deal of two-way information and influence flow. The professional quality of these interactions is probably enhanced by the fact that formal contract monitoring and fiscal arrangements are delegated to one or another military service agency.

There is also encouragement by DARPA for participation in larger open meetings and conferences of a professional nature. Contacts at such meetings are a major channel through which membership in the DARPA community can be enlarged.

3. Encouraging inter-institutional linkages

DARPA supports university-industry collaboration in a variety of ways. Most obviously it allows and expects subcontracting in either direction and may specify the contractors and subcontractors it wants to work together. It also supports university-industry knowledge exchange through meetings and sometimes through the award of fellowships or internships where industry people can take time out of their work to observe and participate in on-campus university projects.

There is also support for industry-military collaboration and academic-military collaboration through the working out of "test bed" arrangements with one or another military command.

There is some question as to how far DARPA's enthusiasm for networking extends. Many in academia, in the private sector, and in the military feel excluded from the DARPA circle, yet the Agency rarely makes a strong effort to reach out beyond those that it is currently working with.

4. Adequate and sustained fiscal support

Thanks in large part to a respectful Congress and fairly continuously supportive DoD leadership, DARPA has had the luxury of being able to provide adequate funding for most if not all the project and programs that it has deemed worthy over the years. At the very least it has been able to give enough reliable long term support so that key investigators have not needed to scramble for additional support elsewhere, as is often the case with support from other sources such as foundations and federal sources trying to cut budgets and stretch resources. This kind of support breeds strong loyalties. Support is also typically fairly long term [three years or longer] after initial promise has been demonstrated. There also appears to be a greater allowance for flexible use of funds than we see in most government contracts and greater latitude in expectations of products to be delivered and schedule of delivery.

Until recently, DARPA's procurement system was relatively trouble free. However, since 1982, processing time from initial review to funding has increased dramatically. In part, this increase can be traced to changes in acquisition regulations since that time. When the Competition in Contracting Act (P.L. 98.369) went into effect April 1, 1985, the slope of this increase became even steeper. Altogether, processing time has doubled from about 60 days to about 180 days between 1982 and the present. This increase is attributable to two major problems with the recent law. First, the new regulations require more contracts to be placed for competitive bidding (only contracts under 10K are excluded altogether). Although approximately 70 percent of DARPA's unsolicited contracts are less than 300K and only 5 to 10 percent are over 500K, the 10K threshold is so low as to be meaningless. Prior to 1985, about 10 to 15 percent of DARPA's contracts were competitive. In 1985, the figure will rise to 25 percent. Second, the 1985 Act distinguishes sharply between 6.1 (basic research) funds, which are exempt, and 6.2

(development) funds, which are not. In reality, the 6.1 /6.2 distinction is a fuzzy line at best. One of DARPA's concerns is that while the larger firms can afford to wait, the time consuming administrative procedures are most damaging to the smaller contractors, those often responsible for in-transfer of major innovation, and, ironically, the group that Congress hoped to benefit when it passed P.L. 98.369. Clearly the new procedures threaten this aspect of DARPA'S long-standing modus operandi, substantially reducing flexibility and the capacity for rapid response to new challenges and opportunities where fiscal support is required.

5. Pressing for movement toward downstream applications

In spite of what might appear to be a looseness of control from the items cited above, DARPA nevertheless retains firm policy control and program direction. Unlike other agencies which fund basic research, they also conceive and execute projects within a longer term integrated program framework.

Furthermore they encourage and even force linkage between persons and organizations with more basic/generalist concerns on the one hand and those with more applied/particularist concerns on the other. Sometimes they also encourage involvement by the military services in up-stream developments and support interactions between military units and researchers in private firms and universities [see section below on "hand-off"].

In recruiting staff, DARPA looks for professionals who take a broad view of technology development, share their strong concern for downstream application, and have ideas about how to facilitate the transfer process and the management of R&D programs in general.

6. Promoting creativity

DARPA staff engage in flexible project monitoring to allow investigators to pursue new leads wherever they may take them within reason and plausible relevance. They also undertake continued surveillance of technical developments nationally and internationally as well as within programs to make sure that promising ideas developed elsewhere and promising talent grown elsewhere are not missed.

Some DARPA staff report that they pay special attention to the views of outriders and mavericks within the DARPA community and occasionally promote maverick projects as correctives to in-group ossification.

There need to be two qualifications to this emphasis on encouraging creativity. First there is not much interest in many types of formalized communication procedures, especially the print/journal system and clearinghouse-type operations. There is a confidence among many staff that they already are on the cutting edge of developments and the way to stay on top is through attending meetings and staying in close communication with the known leaders. In contrast it may be perceived that what could be gained by extensive library research, journal reading, and the searching of bibliographic data bases would not be new and such activities could therefore not be viewed as creative.

Compatible with the above observation is our perception that not much effort is expended in seeking out new ideas from outside the DARPA community unless they clearly relate to current program thrusts. Although there are instances of new initiatives in response to outside developments [e.g. in bio-technology], the seeking out of new areas of innovation is a rather haphazard process. When an effort was made in the recent past to systematize that process to some degree [the SRI innovative search project] it was not strongly supported by most staff and was eventually terminated.

7. Supporting capacity-building innovations with circle-back potential.

At least three instances can be cited within the computing area alone where DARPA has commissioned significant demonstration projects with the intent of making use of the resulting systems in other computer R&D projects. The earliest example of this that came to our attention was the development of ARPANET. This innovative computer conferencing and messaging system has been made available to all members of the DARPA community including university-based, industry-based, government-based, and military service-based computer R&D persons. It was the opinion of those interviewed that the use of the system significantly accelerated progress on other projects by making the exchange and integration of technical information from diverse sources easy and rapid. It also allowed DARPA staff ready access to on-going developments, making project monitoring easier, less intrusive, and more extensive. Finally, rather than obviating the need for meetings, the ARPANET was reported to have greatly strengthened their value because participants could begin to interact quickly without the need to catch up on what others had been doing since the last meeting.

A more recent achievement which may come to have great impact on the acceleration of computer R&D is the MOSIS program which allows very rapid custom fabrication and delivery of silicon chips based on designs from thousands of different designers including students taking design courses at different universities throughout the count /. The Institute for Scientific Information at the University of Souther California manages the interface between requestors and a number of chip foundries. The MOSIS facility now serves as a tremendous resource not only for all DARPA-connected R&D projects but for all requesting NSF grantees and all R&D units in the military among others. Thus it has developed a national resource of great potential importance to the evolution of a national capability in the computer development field.

Within the strategic computing program the three large demonstration/applications projected each is intended to serve as a test-bed for many present and future R&D projects in ways roughly analagous to the MOSIS project. Thus multiple remote access from both universities and other firms will be included as a design specification for each.

C. Implications for Type 1 Transfer: Changes in the Modus Operandi

There is no area where we can say with total assurance that there is no room for improvement, but we have found much to admire and not too much to question in the way the agency manages 'intra-program transfer'. Another way to say this is that it performs its own self-designated tasks very well. This includes effective linking of more basic to more application-oriented projects, universities to industry, universities to other universities, and DARPA-supported researchers to other DARPA-supported researchers within a program area. However, DARPA is noted to have a weak institutional memory and has no mechanism for self-evaluation. Partly as a result it also lacks a coherent planning process and may be missing important opportunities to increase its productivity and effectiveness greatly. We believe that improvement initiatives could be taken in each of these areas at minimal cost and minimal risk to continued productivity.

1. Strengthening the institutional memory

DARPA is especially crippled by a weak institutional memory, noted several times over in a previous historic review [Barber, 1975] and strongly confirmed by our own interviews. This is a shortcoming that can be overcome by management action. First of all, the Barber report just cited should be required reading for all staff. Prepared under the direction of former DARPA program manager Lee W. Huff with Richard G. Sharp, this report of 600 pages covers the period from the founding of the Agency in 1958 to 1975. It is a thoroughly documented and remarkably well written narrative, providing a history of all major programs and divided into periods representing the tenures of each DARPA director. It illustrates a remarkable continuity of Agency characteristics and problems over time, and the picture it draws in 1975 is highly consistent with the picture we have drawn in 1985.

Beyond mere reading, DARPA should institute a series of internal seminars on specific management issues, reviewing selected portions of the Barber volume and other sources and bringing in former DARPA staff members and directors as appropriate.

The history of the Agency from 1975 through 1985 should also be undertaken, following the lines of the Barber study and a regular program of case studies should be initiated to document selected DARPA initiatives. Despite the fact that DARPA can make numerous claims to be an exemplary promoter of advanced technology and manager of federal R&D dollars, documentation of how its programs actually function are lacking. DARPA programs deserve more self-conscious scrutiny, and case studies of both on-going and completed projects in selected areas could yield numerous targets for system improvement. Such studies should take special note of technology transfer issues.

In fine tuning its strategy DARPA staff should be asking a number of questions of themselves for which answers are not now but could be forthcoming. For example: [1] re DARPA program leadership style: what makes some types of DARPA leadership more effective than other types? [2] re DARPA-organized meetings: what makes one meeting better, more important than another? how much, how well, how rapidly do important items spread from such meetings [diffusion, leakage]? [3] re networking: what is optimal network size? how much interaction constitutes optimal network involvement? is there such a thing as too much? what types of people need to be involved at what levels? [4] re linkage: how much forcing of interaction and collaboration is necessary or desirable? are some gaps too wide for direct linking efforts to be cost effective? are there linkers who can fill in these gaps? is this a role which DARPA plays adequately? [5] re core elites: are some important leaders left out? are important dissonant voices given an adequate hearing? does dependence on elites interfere with the need to keep building a larger national infrastructure of competent R&D centers? [6] re the contracting process: do some Service fiscal agents serve more effectively for providing military hand-off than others? when is it optimal to go to competitive bidding? does competitive bidding rule out some of the best people because they do not want to compete?

Obviously answers to such questions, even on a tentative basis, would be highly valuable for improving the management of programs. Such answers can only be derived from empirical analysis of recent past and current projects. This means conducting careful case studies and making comparisons across cases on relevant dimensions. Cases would trace inputs, decisions, and outcomes over the life of a program. They would record critical events and descriptive facts such as:

[1] Key actors: contractors, consultants, DARPANS, others: Who gets invited to meetings and why? Who gets well informed on what is going on?

[2] Decision points: types of decisions, process of decision making, persons involved, what informed the decision, was it clear at the time how important the decision was, what implications it might have? Who was responsible for implementing the decision? Were implications for implementation thought through?

[3] Key meetings: Who called? Why? When? Agenda? Process? Written output? Decision output? Clarification output? Consensus output?

[4] Disagreements, conflicts: frequency, substance, function of, other problems caused by;

[5] Stages of program growth and maturation;

[6] Attitudes re planning process, fidelity to or deviation from plans;

[7] Marker events: demonstrations, discoveries: Who? When? How? How revealed and disseminated?

[8] Containment issues: do they arise? how often? what is the level of concern? what is the level of consensus? what actions are taken?

Such documentation does not constitute an institutional memory in and of itself, of course. It must be accompanied by the development of a filing and retrieval system for the documentation which can make information on any aspect of past program experience quickly accessible.

2. Creating a mechanism for self-evaluation.

Case studies and other documentation are pointless if they are not conscientiously and regularly used as a self-appraisal device by managers. Mapping of program progress and plans in terms of transfers and transitions might follow the examination of a number of case studies. What one should be looking for here is some kind of template or management tool which would suggest when programs are approaching critical stages for which certain kinds of meetings should be held, where certain kinds of advice or collaboration should be sought, [e.g. from other experts, from a military service, etc.]. These stages would probably include proof of concept demonstrations, significant expansions of effort, initiation of work within a private firm, classification, conception of a specific military application, transition to a military service, and termination.

3. Instituting a coherent planning process

The extroardinary informality of the planning process at DARPA is often touted as one of its strengths but we believe that such an assumption should be scrutinized carefully and compared with various optional approaches. The kinds of on-going case studies, seminars, and program reviews suggested above are rather gentle and unobtrusive ways of doing this. In the longer run, however, we would expect that management would begin to move beyond self study and start to experiment with the use of management and planning tools reflecting an increased wisdom of the program development process. For example, certain types of project reporting might be instituted, and managers might want to develop checklists to cover periodic monitoring of certain aspects of progress and potential trouble that have been routinely passed over or under-reported in the past. In evolving new management strategies DARPA would of course rely heavily on the types of self-appraisal indicated above but there are also a number of other intellectual-technical resources which could be drawn on as suggested below.

The knowledge transfer framework developed in this report could represent a start toward a more systematic approach to planning. The notions of *stages of development* and of *transitioning* between stages and between insitutions are fundamental building blocks of the planning process at the conceptual level. How technology moves from a basic to an applied form should be the core process which concerns DARPA managers. For example, there will be times when it is appropriate to involve only university study groups on an informal basis, other times when contracts should be let to universities, other times when joint arrangements should be developed involving both universities and private firms, other times when competitive bidding should be the primary mode, and yet other times when Service units and/or laboratories should be heavily involved. Although there are no firm dividing lines and each program will have some unique requirements, wise judgements depend on knowing what stage the technology has reached and what the past experience has been [positive or negative] when programs have been managed one way or another.

At the front end of this process where new programs are being formulated it is especially important to organize the planning effort in such a way that a wide range of ideas and options from *diverse* sources are actively solicited and seriously reviewed. We discuss this aspect again under implications regarding "in-transfer".

The planning process must also involve considerations of military hand-off including the involvement of appropriate personnel from the relevant DoD units. This is discussed further in the next section.

The Strategic Computing Program seems to represent a new departure for DARPA in instituting a coherent planning process. Consideration of many of the issues discussed above are reflected in some of the planning documents related to that program. Even the mere fact that there are planning documents witn bench marks and timelines and estimations of level of effort by task indicate a move in this direction. The program is extremely ambitious and has been criticized in some circles for being so, but it is important for the Agency to aim high and, with the planning process, to see what is possible. The SCP is thus not only a test for DARPA and for the ingenuity and capacity of US computer R&D but also for the planning process itself.

4. Nurturing multiplier projects to enhance managerial functions.

It is wrong to view DARPA as just another funding agency for R&D projects. Rather it is an agency which orchestrates an R&D system. The activities it supports are generally integrated with one another in meaningful ways; they build on one another and some of the most important serve as capacitating mechanisms for many or all other projects and researchers in the system. This is one aspect of DARPA which is especially important and perhaps unique. The question might therefore be raised: is the Agency doing all that it could possibly do to find and encourage such projects?

There are at least two areas where such multiplier projects might be found. One of these is in the application of artifical intelligence systems to the work of DARPA itself. DARPA has long been considered the leading supporter of AI research in the United States. A major AI application area is management information systems and aids to decision making. Thus DARPA has the best access to state-of-the-art AI and should be applying that knowledge to its own managerial craft. We suspect that a special project would have to be initiated through contract to begin such an application. To minimize risk to on-going programs, presumably it would initially be conducted with only one program, probably as a redundant parallel mechanism with existing management processes rather than a complete substitution.

A second area might be the experimental use of behavioral science techniques to improve various aspects of system functioning. The applied scientists and engineers who lead DARPA have up to now relied exclusively on ad hoc processes and their own instincts as to what constitutes 'good' R&D management. They may feel they have every reason to be confident in their own instincts, considering the apparent success of the Agency on balance. However, if they are really concerned about optimization of the system, they should at least be open to the application of state-of-the-art behavioral science procedures in certain domains of system management, possibly including any of the following:

[a] meeting structure and process
[b] decision making structure and process
[c] network optimization, expansion, strengthening
[d] optimization of key linkages, relationships

The Barber report [1975] underlines a long-standing ambivalence of the Agency regarding behavioral science research which was phased out over a decade ago. However, we are in a different era; the state-of-the-art in behavioral science including management science has also changed; and the types of applications proposed are very different from those undertaken in previous times.

There also is good reason to consider the AI and behavioral science approaches in tandem; appropriate AI systems for management will have to account for the behavioral realities and behavioral science approaches probably will not be efficient or accepted without various kinds of computer enhancement.

Chapter Three. THE MILITARY HAND-OFF

The primary if not the sole measure of DARPA's success as far as the Congress and the Executive Branch are concerned is the value added to the national security of the country over a long period of time. Although there has usually been high confidence in most quarters that that value has been returned many fold, there has never been an attempt to measure it or even to document how it comes about. Clearly the hand-off of DARPA-developed technologies to the agencies of government concerned with national security deserves the highest priority consideration as a technology transfer issue.

There is no one mechanism for the transfer of DARPA-developed technology into the military services. Rather, there are many mechanisms employed, all intended to support linkage between DARPA and the myriad other units of the Defense Department which could derive benefit from DARPA's output. To get a picture of how this hand-off process works, we probed this area in some depth with each DARPA staff person interviewed. To round out the picture we also interviewed a sample of 18 present and former Defense Department officials who had worked with DARPA over the years. Respondents were selected from each of the three uniformed services as well as from DoD level and from one defense-related civilian agency. They included three senior military officers, five senior headquarters staff persons, and nine program or project managers. This section is based on interviews with both the DARPA officials and these other experienced observers of the hand-off process.

DARPA staff and military observers agree that successful hand-off is a most important concern for the Agency, for the Services, and for the country. However, there appears to be considerable disagreement about how well it is working, with DARPA staff being generally satisfied but a significant number of their DoD counterparts generally dissatisfied with present arrangements and results.

In examining cases, it is possible to point to a number of failed transfer efforts as well as a large number of outstanding successes. Even though the success stories give strong evidence of DARPA's value, the frequency of failure, the persistence of conflict and the consistency of certain criticisms of DARPA's approach suggest that the process needs to be reviewed in great detail to determine if there are ways in which it could be improved.

With regard to Strategic Computing in particular the picture is currently much brighter than in other areas. The Services can point to a number of past hand-offs of important developments in computer technology [e.g. project MAC], and they are optimistic about future prospects. The most frequent comment runs something like: "this is exactly the kind of thing DARPA should be doing" in contrast to many other cases that are frequently cited as examples of poor linkage to the Services [e.g. Assault Breaker, Forward Swept Wing]. However, much of this positive glow may result from the facts that [a] computer research has been a winner in the past, and [b] Strategic Computing has not yet reached the demonstration stage where almost all DARPA's problems with the Services tend to begin.

We have identified thirteen mechanisms that are used with some frequency, usually in combination, to strengthen the linkage between DARPA and the Services. There are also a few mechanisms that are either not used or under-used, which might further strengthen the linkage. In the following pages we provide an analysis of both types.

A. Facilitative Mechanisms

1. The procurement process

The procurement process which is delegated by DARPA to the military services is seen as an important way to get Service involvement in DARPA programs. According to one DARPA staff member, for example, Services actively compete in some program areas to be the procurement unit. Alert program managers do succeed in getting serious service involvement and a sense of co-ownership in some programs (e.g. Ada). On the other hand, it seems surprising that we have found no instances where the Services either contributed significantly, impeded, or caused conflict in the execution of any DARPA program through the procurement process. Some military procurement officers complain that DARPA discourages their direct involvement in contracted work at universities, not permitting site visits for fear of stifling or over-directing the research effort. An instance was cited where the Service representative insisted that a university research project comply with reporting requirements over the objections of a protective DARPA staff person. Subsequently, according to this informant, the university people actually were enthusiastic about the positive impact produced on their research by the discipline of required periodic reporting. Nevertheless, bad feelings persisted between DARPA and this service agent for a number of years afterward.

2. Military membership in the network and ARPANET

Numerous military personnel and military R&D facilities are connected to ARPANET. Thus the possibility always exists of ad hoc involvement by the military services on the initiative of particular individuals. As we understand it, some of the intensive group interaction in relatively small closed circles which is a principal feature of the DARPA modus operandi [see again Section I above] specifically allows participation by relevant military personnel. Thus it may be easier for a military person with special interests in a technical area to gain admittance than, let us say, an engineer in a small civilian sector high technology company or a less prestigious unaffiliated university. However, to get appropriate and strong military involvement probably requires a strong effort by the technical people in DARPA to reach out to the Service units that might be relevant. It may even initially require bringing in military R&D people without being fully certain that they are relevant, fully technically capable and fully able to contribute to the proceedings. DARPA does not like to load up important closed technical meetings with extras and does not view these as educational meetings or meetings to link to the Services. Yet clearly it is in such meetings that the crucial linking within the DARPA community goes on. This is an area that needs further exploration.

3. Contractors as bridges between DARPA and the military services

DARPA contractor firms are also typically contractors and vendors to the Armed Services. Such firms are frequently identified with particular Services, have a long history of working with them, and have numerous retired military personnel on their payrolls. The more applied the project, the more this will be the case. DARPA contractors also have a built-in incentive to further develop military applications from DARPA-developed technology and to seek out military markets for resulting products. However, in so doing there is no incentive for such firms to *credit* DARPA for providing them with such advanced capabilities, whereas there are strong incentives (a) to claim sole credit or (b) to share credit with the purchasing service. Furthermore, there are both marketing and technical reasons for collaborating with the purchasing service to the highest degree. This would of course include using R&D already developed by that Service. There are instances where DARPA and one of the Services were simultaneously funding projects with largely overlapping objectives.

Even firms who are initially outside the DARPA network may have strong incentives to compete for and acquire DARPA contracts to position themselves for later marketing to the military.

4. Creating test-beds in military units.

To a considerable degree DARPA forces linkage between its programs and the military by requiring contractors to work with some military units as "test beds" in developing various items of technology. This is obviously the case in the Strategic Computing program with the carrier battle group battle management system and will also be the case for the pilot's associate program. The test bed arrangement allows continuous interactive collaborative relationships between DARPA-supported personnel and personnel in line military units. The latter may later be crucial demonstrators of the developed technology as well as advocates for its further diffusion and adoption in equivalent units.

5. Program/project review typically includes representatives of relevant services

It appears to be largely up to the DARPA staff program manager to determine who comes to what meetings and reviews. We would surmise that different staff have different levels of concern and different talents for involving military personnel in key meetings. Although there is an informal norm in place that such involvements are important, there is no specific standard and no tracking of actual levels of participation. We found at least one instance where Service contracting agents were excluded from such reviews in spite of their desire to participate.

6. The Defense Science Board

The Defense Science Board is a high level external advisory group funded by DARPA and intended to provide the periodic guidance in terms of national priorities for defense-related R&D. In 1982 the Board reviewed all advanced technology areas and came up with ten which had high priority to move forward; two areas were assigned to DARPA for follow-through. Guidance at this level of generality probably has little impact on DARPA's activities [since it is DARPA's job to identify and track priority areas even before they become obvious at policy levels] and its impact on the hand-off problem is probably nil.

7. Assistant Secretary of Defense for Science and Technology

The ASDST currently wears a second hat as head of DARPA, but this is only since 1981 and may not set a precedent. However, it would seem desirable that the senior DARPA official be involved in and responsible for R&D activities that extend beyond DARPA, itself, for a number of reasons. Most obviously it is important for the senior DARPA official to participate in and have some clout in decisions regarding R&D applications. It is also probably important that the senior official be aware of and sensitive to the needs and concerns of the Services and other defense agencies as they emerge and merge at the OSD level.

8. The Office of the Secretary of Defense

The OSD plays an important coordinative role on some programs, notably the development of Ada and its eventual acceptance by the Services. The value of this connection may vary from time to time, depending on the special interests of the Secretary and Assistant Secretaries. One DARPA informant noted that a current ASD happens to be a real "advocate" for the development of software technology. There is no question that the OSD is an important buffer for DARPA, shielding its programs from Congressional scrutiny and from the more operational concerns of the services. The OSD also plays a crucial role in determining knowledge containment policy for DARPA [see Section IV below].

9. DARPA funding of DoD intra-mural R&D

Some DARPA funds (8-10%) go directly to military R&D facilities. We find very little mention of this fact and not much recognition that it might be important. One outside informant suggested that the military R&D facilities have the same problems with hand-off that DARPA has. Thus transfer to them may only postpone, not solve the problem. On the other hand, it would appear that ownership by the command levels would be higher for projects which are accepted as line items in their own R&D budgets.

10. DARPA briefings for the Department of Defense and the Services

At least once per year there is a briefing by the Director and relevant DARPA program staff for very senior level staff of each service. These meetings are likely to be attended by the Assistant Secretary for RDA, the Deputy Chief of Staff for RDA and key staff officers. It was described by one informant as a "show-and-tell" by DARPA in which they would elicit service endorsement for what they were doing. It was also seen as an opportunity for the Services to discuss their own related projects. Although these sessions are well-attended and highly appreciated, there are some deficiencies. First of all there probably are too few of them. Secondly, they are limited to such a high command level and they are of such short duration that there may not be much penetration of the knowledge or expectations to the working level. It is also unclear what formal policy, if any, governs the timing, subject choice, or invitation list for these meetings.

11. Advanced high quality high technology is its own magnet

DARPA's traditional view has been that high quality state-of-the-art technologies will find their own way to the military marketplace. However, there is no consensus within DARPA on this matter: some staff could be characterized as more interventionist, others less. It may be that the automatic magnet view applies especially well to the computer field where private and public sector innovation have been rampant with accompanying fanfares. However, the popularity of an area does not assure that applications will be appropriate. There may be a tendency to buy too much too fast, to acquire technologies for operational use that are still really in the development stage. Consequences of over-utilization, premature utilization, and mis-utilization can all be catastrophic. There is much concern, for example, that the compliance order from OSD for Ada may lead to serious damage to major weapons systems development efforts. Over-use and under-use are both likely to result from poor linkage between the R&D source and the user organization.

12. Representation of Services on DARPA staff.

Military personnel represent an important segment of DARPA staffing. Nearly one third of DARPA officials with program responsibilities are military officers and more than half have worked in the military services or some other branch of the Department of Defense prior to coming to DARPA.

This fact appears to be both a blessing and a curse as far as hand-off is concerned. The current and past military representation on DARPA staff came in for much criticism from some military observers. It was claimed, for example, that some are officers frustrated that their pet projects have been rejected by their Service. Once on board at DARPA they support funding for these same "rejected technologies" so that it is no surprise that they later can not sell them back to the Service that had rejected them. In any case it appears that officers assigned to DARPA are not obviously selected because they are good linkers to the Services. Sometimes just the opposite may be true. Some may be isolates within their Services and may self-select for just that reason.

13. Program transfer to other agencies.

DARPA has an intermittent policy of transferring programs in their advanced stages to other DoD units [e.g. when the Directed Energy Program including associated DARPA staff was transferred into a new SDI unit outside DARPA]. When DARPA lets go of such programs, it is threatened with staff and budget shrinkage and hence a general weakening of its capacity. It is clearly important for DARPA to be awarded new staff positions and resources whenever there is a successful program transition and transfer of this type.

B. Mechanisms Under-Used or Not Used

1. DARPA staff attendance/involvement in other military events

There seem to be few instances where DARPA staff actually attend meetings or go out to activities which are put on by the Services for their own people, i.e. encounters in which DARPA would be listening and absorbing rather than "showing-and-telling". Heavier attendance at such events might have a number of benefits including:

a. learning more about military needs
b. extending the contact network deeper into the services
c. informal off-the-agenda discussion of new ideas or anticipated /ready DARPA technologies
d. finding appropriate candidates for DARPA staff positions

2. Systematic and routine searching for [past and present] R&D sponsored by any of the Services

There is no systematic effort within DARPA to keep abreast of what is happening in the many hundreds of R&D facilities and contracted projects that are producing results for the DoD. For example, one DARPA official was not aware that "DTIC" was the Defense Technical Information Center, responsible for the archiving and distribution of all defense R&D, classified as well as unclassified . Such searching could be used to look for:

a. identifying overlaps;
b. discredited or heavily warmed-over areas;
c. new ideas/areas;
d. areas of greatest military concern; or
e. opportunities to link DARPA research with other military R&D and with field needs, circumstances.

3. Highlighting the hand-off function within DARPA

One problem with the military hand-off of DARPA technology may be that there is no one person or group or sub-unit of DARPA specifically assigned to it. Everybody is supposed to be concerned with it, but, since priority concerns are always with advancing the technology and maintaining high technical quality, the hand-off function may often go by default. Assignment of DARPA [or other Service] personnel explicitly to the linkage/hand-off function, either in general or with respect to a particular technology might make sense under these circumstances.

C. Implications for Type 2 Transfer: Improving the Military Hand-off

With respect to military hand-off we note a fairly high level of Agency concern and the use of a number of potentially effective transfer tactics. Nevertheless, interviews with personnel from many other units of DoD having relevant connections to DARPA uncover some widespread dissatisfaction with hand-off issues. Historical reviews of past performance indicate that relations with the Services have been strained in many areas since the Agency's inception 27 years ago. We propose several types of activity which might be considered by DARPA leadership to improve these relations.

The military hand-off probably is the one transfer domain which requires the most obvious attention. Despite our listing of 13 different mechanisms that are used to accomplish transfer, there still appears to be significant concern on both the military and the DARPA sides that such transitions occur in a more satisfactory manner. It should be a very high priority concern that the military services and the other national security-related agencies get the earliest possible access to DARPA studies, providing that such access does not interfere significantly with technical progress on those studies. What seems to be most obviously indicated is some kind of liaison or linkage function above and beyond what is now in place. Such a specialized unit would have the broad mission of facilitating military hand-off for all DARPA programs, designing tailored strategies appropriate to each program, monitoring progress, and initiating special hand-off activities as called for.

There are a number of specific activities that should be explored and could be managed under such a transfer unit. These inc[illegible] the following:

[1] More DARPA briefings and a revised briefings policy.
[2] More careful and clearly rationalized recruitment strategy for DARPA staff from the Services.
[3] More attention to interface problems between DARPA and its Service procurement agencies.
[4] More involvement in the budgeting and requirements setting process across DoD.
[5] Institute a mediation process for most serious turf battles.
[6] Establish better military access to DARPA R&D outputs.
[7] Consider providing technical assistance to actual and potential users of DARPA technology in DoD.
[8] Set up a mechanism to encourage continuing transfer and utilization activities for technologies which have been developed and are no longer in the active DARPA portfolio.

1. The high level briefings that are sometimes referred to as "DARPA days" have a valuable function in promoting DARPA's image among top military leaders but there is not enough meaningful involvement of middle management and technical personnel who are important in downstream procurement decisions. When technologies are beginning to show promise of downstream application to a particular Service, DARPA should begin to solicit active involvement in the form of suggestions and consultative discussions with operational personnel from the relevant Service units. This should lead in many cases to beginning line items for the procurement and further development of that technology *even if the line is initially set at zero funding*. Hand-off should thus be seen as a systematic step-wise process in which more and more specific involvements are sought from different levels on the Service side as development proceeds.

2. DARPA should probably pay much more attention to the selection process for DARPA slots given to Service personnel. It is especially important that DARPA award positions to people who are also valued by the Services, and will return to be powerful advocates of proven

technologies. At least some of the Service personnel should be real linkers to the Services who will later return to responsible positions and serve as strong and credible advocates for DARPA-developed technologies. It has been claimed by some Service respondents that some of those attracted to DARPA are mavericks with pet ideas long since extensively reviewed by their service and rejected for sound reasons. We think there is still a place for such mavericks and their ideas within DARPA but such persons probably do not serve well as linkers. Since part of the problem may reside in the various military commands reluctant to give up their 'best' people and partly in the career ladder traditions of the Services, DARPA might have to persuade DoD to use more muscle to shake loose appropriate people.

3. Something should be done to re-examine the relationships between DARPA program people and Service procurement people. There appear to be frequent conflicts and resentments harbored by some Service procurement units assigned to administer DARPA contracts. We are not sure what the root cause of such conflicts are or whether they are a necessary by-product of what is essentially a good practice. However, it might be well to make a program-by-program review of these relationships and consider whether the most appropriate units are always selected, whether a better specification of ground rules, a more appropriate division of labor, and a better involvement process could be initiated. We would judge that there are some relationships which work very well and could be used as models for others.

4. There should be a much greater awareness and involvement by DARPA in the budgeting , procurement, and requirements setting process across DoD, especially with regard to the R&D budgets and goals of other DoD units [which collectively are many times the size of the DARPA budget]. Consideration should be given to how the DARPA program fits in with others, especially in sequence, and other units should be encouraged to begin budget lines even at zero levels for technologies that they will be expected to pick up from DARPA in the near future.

5. For those few areas where serious disputes, turf conflicts, or other concerns divide DARPA from the Services or other DoD units, it may be appropriate to consider instituting some kind of semi-formalized

consensus development processes. At least on an experimental basis it might be appropriate to apply systematic decision models to resolve DARPA-military disagreements on such matters as appropriate projects, budget allocations, and transition points for technologies from demonstration to prototype phases. Perhaps some sort of review board could be created to work on long-standing disputes in critical areas.

6. For many years DARPA has had a Technical Information Office which has the responsibilitiy of collecting and maintaining files on all completed projects. However, because of a frequently voiced concern that DARPA reports are hard to come by, it is time to re-examine how this office functions and how effectively it interfaces with both program managers and requestors inside and outside the Agency. An improved technology transfer capability will depend heavily on a streamlined report storage and retrieval system which exploits state-of-the-art records management technology.

7. Through a special contractor DARPA could develop the capacity to provide technical assistance on utilization to other DoD units which are in the process of adopting DARPA-developed technology or are indicating some interest in doing so.

8. There is also a need to develop the capacity to continue transfer efforts on projects that have run their course. This is part of the task of establishing an active institutional memory discussed above. The Barber report cites an instance [p. VI-54] where a DARPA program manager in the 1970's proposed the use of the PLATO instructional system in a joint program with the Services on computerized instruction evaluation, oblivious of the fact that PLATO was initially developed by his own office!

Because hand-off is so obviously a dual responsibility between DARPA and the various receiving units, these other units should also be encouraged to invest in the "pull" of DARPA technology into application. Each of the mechanisms suggested above is proposed as a "push" initiative from DARPA to other DOD units. Each has some sort of counterpart on the pull side and these should be fostered at least as much as the DARPA-generated transfer efforts. Indeed, it is arguable that support for all the hand-off activities envisaged should come from the benefiting Services and should not cut into DARPA's limited budget or staff pool.

Chapter Four: DOMESTIC SPIN-OFF

It is likely that DARPA has had considerable effect on the domestic economy through the spin-off of DARPA-originated and sponsored technology advances. However, unlike NASA, DARPA has no legislative mandate to encourage or even to evaluate such spin-off.

It is a very reasonable supposition that DARPA spin-off has been important for the national economy not to mention the economies of all the NATO countries. It is also reasonable to assume that there has been a great deal of spin-back to the military services and the Armed Forces of NATO in general. However, it is another matter to suggest that there is a technology transfer *problem*. Indeed, there is evidence that some private firms in the technology arena are very eager to acquire DARPA contracts so that they can break into the most advanced areas to anticipate future demand from both military and civilian sectors.

An important category of spin-off which may not be well-served by existing market incentive mechanisms is to the non-military *public* sector [much of which may also have military or national security implications]. Many agencies of the federal government, for example, do benefit from DARPA technology spin-offs [e.g. navigational satellite research which is expected to have a major impact on the FAA after declassification]. Some of these spin-offs might be saving the federal government many millions of dollars as well as improving performance of many functions. Yet it seems likely that the potential for such transfer is hardly scratched under the present circumstances where no one has responsibility for such transfer and there are no clear economic, structural, or legal incentives either on the DARPA side or the recipient agency side.

A. DARPA's Impact on the Computer Industry

The history of computer development from its beginnings in the 1940's through the 1960's [cf. Katz and Phillips in Nelson, 1982] clearly shows that military funding was responsible for almost all major advances in computer technology in those years. Government and mostly military support continually led commercialization and made commercialization possible. Although in recent years market forces have been emphasized in popular accounts of rapid advances in the industry, a closer examination reveals that almost all innovations were initially supported by government research, and since it entered the field DARPA has been one of the major actors. We believe that it would be very instructive for DARPA to trace its influence on the contemporary computer industry for a number of reasons. First of all, such a tracing would likely provide substantial evidence of the value of DARPA and DARPA's approach to R&D support in enhancing the economy generally and thus in fostering a national capability in data processing which, in turn feeds back into our military capabilities. Secondly, it seems possible that such a tracing might reveal instances where spin-off to private sector commercial applications produces a *spin-back* into the military services of important new technical capabilities as when microcomputers [essentially a private sector application] are adopted by military units to perform a great variety of tasks.

One instance of recent significance is the Apple Macintosh computer which contains more than one important innovation directly attributable to prior DARPA-supported R&D. Two staff members interviewed for this report use Macintosh computers regularly in their work and others are reported to be scattered about the Agency. It seems likely that many more instances of spin-off and spin-back can be found.

B. Implications for Type 3 Transfer: Should Anything Be Done about Non-military Spin-off?

Private sector spin-off is not generally viewed as within DARPA's purview, and the Agency is almost totally inattentive to this topic. However, we believe that such a posture is ultimately shortsighted, leading to lost opportunities which could ultimately have national security implications and leading to a needless waste of taxpayer investment in R&D. Lack of attention to this area also probably leads the Congress, the Executive Branch, and the general public to a gross undervaluing of DARPA's overall contribution to national strength.

There are numerous indications that DARPA spin-off to the private sector has had diverse and enormous impact on many sectors of the US economy, particularly the computer industry, and hence the economy as a whole. Yet DARPA does nothing to track these spin-offs and has never assessed their full significance. We argue that it is important to begin doing so for at least three reasons. First, there is a need for an objective accounting of the full societal benefit of DARPA's programs to give both the Executive Branch and the Congress a basis for continued or expanded funding overall or in selected areas. This cannot be done without tracing program effects into non-military areas. Secondly, it is important for DARPA to fully understand the private sector spin-off process so that it can then direct those concerned with military applications to take full and early advantage of the applications that are being developed. Nearly every civilian application is 'dual use', i.e. has a potential military counterpart application, and the military should be given first crack or at least an even start on any advances that are reaching operational level. Thirdly, because many DARPA initiatives do not eventually lead to the military applications that were initially conceived, but do have outcomes which are of potential value either to the scientific or business communities, there is an obligation to assist the transfer of either programs or the knowledge derived from them into channels that can carry them further. This should be done for the simple reason that any federal agency has the obligation to see to it that taxpayer investments are not wasted and redound to the maximum benefit of the society as a whole. In the past DARPA has recognized this obligation for certain programs such as the Arecibo radio telescope which was eventually transferred to NSF so that its great value to astronomical science could be continued. It is also the case that many unanticipated positive consequences can accrue from such efforts which redound to the benefit of national defense. An example which could be cited is the origin of the greatly productive computer processing program in a computer that the Air Force could no longer find a use for in 1961.[Barber, op cit., p V-49]

Among the initiatives that might be considered are the following:

1. Conduct an assessment of how much spin-off there has been from different programs and what the dollar value or tax revenue value of such spin-offs has been.

2. Encourage spin-offs with high spin-back potential. A clear example

of this is the MOSIS program for producing custom VLSIC silicon chips in large numbers. All universities now have access to this system, and it is partially funded by the NSF [an example of interagency spin-off comparable in some ways to the Arecibo telescope spin off 15 years earlier]. There is a strong expectation that the Services will benefit in multiple ways from this greatly increased capacity to train circuit designers and to produce chips which will ultimately have innumerable military uses.

3. Consider the possibility of cooperating with other agencies such as the Federal Laboratory Consortium, NTIS, NASA, or DTIC in establishing a special proactive channel for making the private sector aware of unclassified and successful DARPA projects.

Chapter Five:
THE CONTAINMENT OF TECHNICAL KNOWLEDGE

A. How Important is the Problem?

One DARPA staff member has suggested that knowledge containment might be the only current technology transfer problem that DARPA faces in the computer R&D area. A substantial amount of DARPA-sponsored R&D and most of the R&D which it sponsors in universities is unclassified. This is seen as both a necessity and perhaps a virtue. It is a necessity because academics need to be able to publish their work. The best demand an open professional communication atmosphere in which to conduct all of their work, including free access to foreign as well as domestic audiences and freedom to recruit the best graduate students from around the world. The unclassified policy is also probably a necessity because of the looser administrative controls likely to be in effect on university campuses and the practical difficulties of instituting security measures in such environments.

The extent of the problem is not known in any precise way and no attempt has been made to measure it. Nevertheless, it is clear that a large proportion of graduate students working on DARPA projects and under DARPA-supported scientists are foreign nationals, and DARPA places no restrictions on such participation. Although there are many other channels through which important technical knowledge can get out, the most serious drain is probably through those students who return to their native countries after a course of study and deep project involvement. Examples were cited where such students later became key personnel in advanced computer technology projects in other albeit friendly countries [e.g. the fifth generation computer program supervised by MITI in Japan]

B. Containment and DARPA's Operating Philosophy

The open, unclassified communications policy for basic work is further justified as a virtue in that (a) it encourages the best scientists to work for DARPA, and (b) the open and highly interactive environment promotes the best work and the most rapid technical advancement.

However, DARPA's unwritten policy is not merely to leave communication up to traditional academic patterns. On the contrary, it inserts into the process two additional and perhaps crucial elements from the point of view of containment and relative advantage. First of all, it offers all contractors access to ARPANET, its computer-based networking system. Participation in ARPANET is perceived to have been a crucial advantage in some other computer technology advancements such as Ada and MOSIS. Clearly those with access to ARPANET have certain advantages over those without it. The second element is DARPA's pervasive policy of encouraging small scale, usually closed, and always by-invitation-only technical conferencing. DARPA staff are *always* present at such meetings, and through their attendance they are able to keep close track of research in progress well before it is published. From a security stand point such a policy of regular meetings [at least two per year within every major technical sub-area] has three advantages: first, it keeps the most advanced thinking and communicating bounded initially in what are essentially private meetings; second, it allows DARPA to have the earliest window on important new developments which might have serious security implications so that other containment actions can be taken when and if necessary; and, third and perhaps most importantly, the meetings allow a very high order of free give-and-take communication among those present which has the net effect of widening their technical lead over those not in the charmed circle.

Nevertheless, the current arrangement is inherently leaky , making it all the more important for DARPA staff to track progress closely and to determine just the right moment when technology transition can and should take place to private industry. Even there, in early stages of development, government security measures are not imposed in the belief that each company has its own security interests to protect in the very competitive computer technology market. This is also a plausible but unevaluated assumption.

C. The Argument for Relative Technology Lead

From the above reasoning it follows that a certain kind of contained openness actually fosters and enhances DARPA's leadership in technology over all comers. Strong arguments can be made in favor of the policy on these grounds, but equally strong arguments can be made that some kinds of openness allow others, including potential adversaries, to catch up. It would certainly appear that in a free and open exchange between two parties of unequal knowledge, the one with the lesser knowledge is likely to learn more. DARPA has not done much as yet even to martial the arguments for each side of this argument. The assumption of relative advantage remains plausible but unexamined.

D. How to Study and Make an Empirical Assessment

It should be evident from this brief analysis that there are a lot of unanswered questions regarding the containment issue. We believe that a serious effort should be made to find some answers, at least on a tentative basis. The issue is far too important to be left to casual surmise about the US lead or about the benign effects of current policies at DARPA or within industry or universities or the military. Since strong arguments can be marshalled on both the "keep-it-open" or "more open" side *and* on the "tighten-it-up" side, it seems imperative to acquire greater knowledge of the problem. Further enlightenment regarding the containment issue could come in at least five ways: [1] better definition of the problem, [2] documentation of issues through carefully done retrospective case studies, [3] qualitative and quantitative estimations of losses , gains, and trends across the range of items that fall within the computer R&D realm, [4] quasi-experimental studies of information exchange and leakage under different conditions and rules of communication, and [5] economic modeling of interorganizational and international benefits accruing from different types of economic policy when countries differ in relative investments in research, development, and application of technologies and have differentially restrictive communication policies.

1. Taxonomic analysis of the problem

In a paper under development in the George Mason University Technology Transfer project, we explore the dimensions of the containment issue. We propose that the problem can be sorted out into a twelve step sequence of concerns including both the problem of leaking important knowledge to a potential adversary and getting back important knowledge from them. We call this reluctant linkage process "the dialog of the devious". We also note the ubiquitous and leak-prone nature of human networking. It is not possible to block networking completely and probably not even desirable to do so, yet natural networking processes have a way of guiding and slowing down important communications which have the net effect of protecting technology leaders. In the paper we also look at the major findings concerning the diffusion and utilization of knowledge from the point of view of containment, a perspective which, oddly enough, appears to be unique and almost totally neglected by sociologists and communication researchers to date.

2. Case studies of computer-related technologies

A second stage in exploring the containment issue should be the thorough documentation of a number of case instances within the computer technology field where important amounts of knowledge derived from DARPA-sponsored R&D have passed into the hands of others, i.e. either US researchers not within the DARPA R&D community, Europeans, Japanese, Warsaw pact researchers, or the Soviets. It would seem desirable to conduct at least one study representing each of three different circumstances of strategic importance:

a. where US lead seems to be great [e.g. artificial intelligence];
b. where US lead appears to be flagging [e.g. chip fabrication?];
c. where recent Soviet acquisitions have been most worrisome.

In addition we would want to consider leakage evidence and implications at different stages of technology development, starting with the conceptual stage and fundamental investigation which take place mostly in university settings and proceeding on through demonstration to military hand-off when DARPA no longer has any direct responsibility for protecting the knowledge.

3. Qualitative/quantitative estimations of losses, gains, and trends

Another important task which should probably come after the case study analyses is the estimation of losses and gains for given time periods, first in terms of mere counts of items or types of technologies but later in terms of dollar equivalents.

4. Simulation of exchanges under varying ground rules

There is a significant body of experimental communication literature dealing with artificially created exchange, cooperative, and competitive situations. We feel that some of this literature on what is essentially game theory might prove to be quite relevant to the problem of knowledge containment. We would seek first of all to review the current state of this literature and then to compose micro-experiments in which informnation exchange, leakage, and deliberate spying or theft of information were known and manipulated elements.

5. Economic modeling

Economic modeling studies at the micro level of the firm and at the macro-level of the country should shed some light on the effects of differential knowledge containment policies and differential investments in research, development, and commercialization of computer technologies. Our preliminary analysis indicates that the sharing of technical knowledge at each stage of development among competing enterprises greatly enhances the collective probability of success for each competitor and of ultimate gain for the larger social unit comprised of the competitors [see working paper by Levy, 1985, on a line of reasoning derived from Mansfield and Wagner, 1975].

The rendering of such analyses in real world inter-organizational environments is rather more complicated because organizations invest in developmental stages in very diverse patterns, some putting more effort into R&D, others more into commercialization. An illustrative example from the computer field is the contrast between Xerox and Apple. The former company supports a distinguished R&D facility in Palo Alto, California, a facility famous for experimenting with user-friendly work stations and micros. The parent company, for a variety of reasons, did not push hard to get many of these innovations "out the door" [i.e. commercialized], but nearby Apple, with a minimal in-house R&D

capability, a strong need for a new product to boost a slipping market share, and a very aggressive commercialization capability, eagerly adopted the Xerox technology and built it into the very successful Macintosh computer.

The same type of phenomenon appears to apply to the relations among nations. For most of this century the United Kingdom has produced some of the most outstanding leading edge technology in its universities and national laboratories but the transfer to the commercial sector and aggressive exploitation of technical leadership has often appeared to be lacking. In contrast, the Japanese have generally trailed other advanced nations in the development of new technologies but have been extremely effective in exploiting them, once developed, to compete in and dominate the market for high tech products.

There should be two strong lessons in all of this for DARPA. The first is that having technical leadership at the R&D level in no way guarantees subsequent advantage over competitors. If the environment remains competitive, the big gainers are likely to be those firms and those countries which have strong commercialization capabilities associated with aggressive acquisition of technologies developed by their competitors. The second lesson is that technology transfer, either by intent, by passive acquiescence [as was the case for Xerox], or by theft [as is probably the case for much of the transfer to the Soviet bloc] can seriously affect relative downstream strength and gives a significant relative advantage to the recipient. Active sharing of technology among the producers within the United States clearly expands our national capability and serves the national interest. Probably it is also the case that a similarly open posture among allied countries serves the best interests of the alliance. What may be suggested is the desirability of more open communication among the western countries and within the U.S. especially, coupled with more safeguards against leakage to non-NATO, non-OECD countries.

Yet there may be an inherent contradiction here because the more inclusive our allied network becomes, the more difficult it is to contain the knowledge so that adversaries cannot get at it.

E. Bargaining with High Technology "Chips"

As a final issue under the knowledge containment rubric, it may be important to consider the possible implications of a commanding lead in computer technology for international bargaining, especially with potential adversaries. The meaning of such a lead and how it can or cannot be used as a kind of bargaining chip in any type of negotiationing situation is not known. However, recent developments in strategic arms negotiations between the U.S. and the U.S.S.R. suggest the threat value of a technical *potential* even when that potential has not yet been realized either in a prototype or in an operational device with military significance.

If it were possible to use technological leadership directly as a tool to gain advantage in international dealings, it might have enormous significance for military budgets and the allocation decisions of military planners. It would mean, in effect, that procurement of R&D under some conditions might be more advantageous to national security than procurement of more conventional operational weaponry. It might also mean that R&D should be pursued on a much wider range of possibilities than one ever contemplates for actual deployment.

But can we use a technological advantage in this way? A brief review of the history of military innovation might suggest that those who exhibit an early advantage are often not the leading beneficiaries of their own cleverness. Indeed, the display of technological leadership may have more negative than positive consequences for the leader. First it shows what the technology is [one has to make a credible demonstration to prove one has the technology], giving the other side a clear objective, and second, it provides a strong incentive for the other side to catch up by whatever means possible. In our time this phenomenon has been dramtically illustrated at least twice: first, when the United States demonstrated the atomic bomb and stimulated the Soviets to catch up as soon as possible by espionage and other means; and second, when the Soviets launched Sputnik, stimulating in the U.S. the largest peacetime effort in science and technology that had ever been seen [including, of course, the establishment of DARPA, itself].

What is probably most critical is not the mere announcement of a technical lead or a technical capability but rather the coupling of the announcement with a credible statement regarding one's intentions. The Reagan "star wars" speech may have had a special impact on Soviet thinking, not because it proclaimed a great technological lead in several areas [which it in effect did] but because it included a specific intention to put all the pieces together and make a push toward a prototype system. The down side of this, however, may be that it has alerted the Soviets to the fact that something is possible which they had previously thought not possible based on their own progress in various technical areas including computing.

There are no obvious answers in this realm but it is clearly an area that requires exploration and possibly quasi-experimental manipulation along the lines suggested in item D-4 above.

F. Implications for Type 4 Transfer: What Can Be Done about Containment?

The knowledge containment problem comes to the surface only periodically and the obvious importance of this topic has not been matched with concentrated efforts even to define what the problem is, let alone considering potential countermeasures. All DARPA's contractors share a great concern for the security issue but few if any are able to propose significant steps which could be taken directly and immediately to ameliorate it. There is a general fear that significant new restrictions on communication within the DARPA network would reduce creativity and productivity and might thus have a net negative effect on the nation's standing as a technology leader. Most obviously, however, the Agency could move on four fronts: [a] establishing a more explicit set of policies on containment, [b] gathering data on the extent of contacts and potential sources of leakage, [c] conducting experimental studies to get at answers to some fundamental dilemmas, and [d] using various means to increase contractor sensitivity to containment issues.

The major implication is that this area needs a lot more thought and study, especially some empirical study, e.g. even an enumeration of nationalities of people working on projects; types of meetings they attend; types of publication they engage in; where they go when they leave graduate school, leave DARPA projects. It has long been understood that there is a trade-off between the stronger US capacity derived from an open system and the weakened competitive edge allowed by this same openness through the leakage of important advances. Can we make any assessment of what the trade-off really is? Is it the same in applied as in basic technology? Is it the same with potential adversaries as it is with friends? There should be some ways of arriving at at least tentative answers to these troubling but crucial questions. In a companion paper we further explore the implications of these trade-off questions and what to do about them.

There are some real dilemmas related to knowledge containment and progress in research and development. US policy and even world-wide policy up to the present makes the assumption that basic research either cannot or should not be contained in any way except through the sometimes severe policing of the academic refereed journal system and its associated hierarchies of presumed excellence. That system tends to give widest distribution and publicity to what is seen by the academic community as important and valid knowledge; thus it works in a manner that is totally at variance with national security interests.

Yet there comes a point in the progression from research to development when the knowledge is suddenly "hot", where its applicability to national security matters is seen by its holders as very high but not yet fully exploited. This is the point at which the security curtain is supposed to come down with a thud because the speed of exploitation of the basic technology from here on will represent the technology lead factor over any potential adversary. Yet there is no sure way of determining when that point is either in advance or even at the time it happens!

Further complicating this picture is the fact that for a variety of reasons the need for and the desirability of containment decreases again as development proceeds toward production and deployment, and when the knowledge is becoming "cold". The greatest conflict between the knowledge producers and the knowledge containers is likely to occur at these two points, the critical heating up point and the cooling off point. The hard choices for DARPA are mostly at the forward end of this curve when the knowledge is becoming hot. The posture which DARPA takes in general we believe to be a fairly shrewd one under the circumstances, namely to keep on top of developments, trying to contain the sharing of the latest developments to small and informal closed gatherings in which DARPA staff are involved and imposing security constraints not through blanket rules but only at what seem to be the right moments. This sounds good but there has no effort to date to trace such a process empirically for any evolving technology.

In summary, there appear to be five implications for action in this area:

[1] Develop a consistent policy or posture on knowledge containment backed by a clearly articulated rationale, even if there is no empirical data to support it;

[2] Conduct a round of meetings with network members to explore the issue and possible counter-measures;

[3] Move toward a better empirical understanding of the real dimensions of the problem and the nature of the problem;

[4] Move to a better understanding of the costs and benefits of potential countermeasures through modeling and experimentation;

[5] Consider diversification of the DARPA portfolio as one way to make adversarial intelligence gathering more difficult.

1. An appropriate DARPA posture

Because of its singular role as the generator of basic R&D with military applications, DARPA must be concerned about knowledge containment issues. Security issues may be even more important for the Agency now that it is making computer R&D such a prominent part of its program. As noted earlier, computer R&D poses very special containment issues and challenges.

On the other hand, there are some reasons for caution in implementing any new containment policies within the Agency. The principle among these are as follows.

[a] Although DARPA-developed technologies are a precious national resource, there is some reason to believe that the truly serious threat of leakage occurs downstream where the technologies have already been transformed into military prototypes. This is a stage at which DARPA no longer participates in development. While it is theoretically true that upstream development is equally or of even greater importance, current assessments of Soviet interest and capacity to exploit such knowledge are both fairly low.

[b] Key personnel associated with DARPA programs already have a fairly high level of concern about containment issues and wish to be cooperative; however, these same people are distinctly wary of any initiatives which would restrict their current communication and working patterns. The open flow of knowledge is generally viewed as a major reason for the success of DARPA programs.

[c] The informal nature of critical decision-making within DARPA and between DARPA and its key contractors probably makes illicit eavesdropping difficult.

[d] The size and complexity of the DARPA community and its social infrastructure probably makes it very difficult for any individuals not fully involved to derive much benefit from sporadic eavesdropping.

[e] There would probably be considerable resistance to heavy-handed non-consensual measures taken to shut down or restrict channels now used with any frequency by academics affiliated with DARPA programs; such resistance might hinder progress and perhaps even call unwanted attention to certain items which would otherwise go unnoticed by potential adversaries.

Because of the obvious importance and sensitivity of the issue, DARPA should have a coherent, well articulated, and well-defended policy regarding containment. To the best of our knowledge at the present time, it does not. It is also important for DARPA not to act precipitously or to make major changes that could affect its success rate negatively. This means proceeding on the basis of informed analysis of past and present leakage patterns and experimental knowledge of what various alternative countermeasures will likely accomplish.

2. Direct and immediate actions: What can be done now?

DARPA could immediately begin a series of meetings of researchers in its various substantive programs to present the issues and invite suggestions of countermeasures. Such meetings would in and of themselves have a useful purpose in sensitizing the DARPA community to the nature and magnitude of the problem. It could also articulate an official DARPA policy regarding containment or any sub-issues within the larger issue of containment as identified in this paper.

Substantively such meetings might include the following elements:

[a] Review of recent past statements, analyses, and policy pronouncements such as Weinberger, Feb 1984; National Academy, 1982. Points of relevance to DARPA community should be delineated; changes, up-dates, accuracy, and points of dispute noted.

[b] Rank-order areas of concern, critical channels, types of technology.

[c] Solicit ideas on how to study the problem more accurately, systematicly; determine level of cooperation to be expected for such studies.

[d] Put on the table a menu of potential counter-measures.

[e] Solicit collaboration or input in the development of a DARPA policy statement regarding containment.

3. Understanding the dimensions and scope of the problem

Further enlightenment regarding the containment could come in at least three ways: [i] better definition of the problem, [ii] documentation of issues through carefully done retrospective case studies, and [iii] qualitative and quantitative estimations of losses , gains, and trends across the range of items that fall within the computer R&D realm.

4. The possibilities of experimentation and modeling

There are at least three types of experimentation that might be undertaken to shed more light on the problem of knowledge containment: [a] the study of leakage in micro-experiments of simulated two system interaction; [b] economic modeling; and [c] real time incremental experimentation with various kinds of containment strategies in DARPA projects and programs. These possibilities have already been discussed above [see page 53].

5. Changing the portfolio profile

Because large projects and programs inevitably invite greater attention from unwanted information seekers, DARPA might want to reconsider its long range policy of concentrating heavily only on a few major areas. A more diverse portfolio would be harder to track and might be more valuable to the defense of the country in the long run. The larger programs are certainly needed but they may be more properly placed in agencies which exert greater control over information channels.

Chapter Six: ENCOURAGING IN-TRANSFERS

A. Importance of In-transfers

DARPA has the special mission within the defense establishment of discovering and exploiting new technologies which *might* have important downstream military/national defense implications. From its creation in 1958 to the present it has managed reasonably well in this regard. However, to assure that it remains on the leading edge of technology, it clearly must reach out into both the academic and the industrial communities and into technical circles in other countries to find whatever is new and promising. Obviously there are limits to this reach-out function, however. DARPA does not support fundamental research across the board, having a narrower purview than NSF, for example. [NSF also being highly selective in program emphases but with a broader span and greater dependence on external judgements of what is "important"] Its special task is to determine whether a research field has progressed to the stage where there are potential downstream applications (a) that have military significance and (b) can be facilitated or accelerated by additional government support.

In-transfers would appear to require three distinct steps which we might designate as:

[1] scanning,
[2] evaluating, and
[3] program framing.

1. Scanning

To fulfill its mission completely DARPA should be able to identify virtually every sphere of scientific activity around the world including all the physical and social sciences and should have knowledge of and access to all the leading scientists, laboratories, and enterprises where such work is going on. It could conceivably do this through monitoring generalist scientific periodicals like *Science*, *Scientific American*, *Science News*, etc. and through calling upon senior scientists with a broad range of interests . It could also conceivably have an in-house cadre of senior scientists [as does the Congressional Research Service of the Library of Congress] who collectively would cover all areas of scientific knowledge. Our interviews suggest that some [and perhaps most] DARPA staff are themselves very good scanners in an informal sense, but there appears to be no scanning function as such and no mechanism in place that assures *comprehensive* scanning of developments in science.

2. Evaluating

Once a promising area has been identified, the next step is to determine whether or not DARPA has any business being involved in it. Four distinct judgements have to be made: (a) are there any conceivable downstream military applications? (b) are these applications potentially important enough to be attended to by DARPA? (c) has the research reached the stage or maturity where DARPA intervention could significantly affect it? and (d) does it have the priority relative to other possible new initiatives by DARPA and within DARPA's budget/resource limitations to require action now? As with scanning, there appears to be no routine mechanism within DARPA for making such determinations although they are clearly made from time to time in an ad hoc fashion.

3. Program framing

When a positive decision has been made to initiate a new program, a number of additional decisions have to be made which still could be seen as part of the in-transfer process. First of all, a program leader or manager must be found [either assigned from within on a part time or full time basis or recruited from outside; when the in-transferred effort is significant and represents an area where in-house expertise is scant, the latter course is generally followed [e.g. Skurnick for bio-technology]. Secondly, based on an initial assessment of the state-of-the-art initial program objectives must be set and a plan must be conceived, at least in a general way of how those objectives might be met over what time period. A third task is to identify and recruit to the program those persons and institutions which appear to have the strongest capacity to carry the work forward. As with scanning and evaluating, DARPA appears to have no firmly established procedures for framing new programs. On the other hand, it should be noted that the initiation of new programs in DARPA based on exploitation of entirely new technologies is a relatively rare event, certainly occurring at the rate of less than one per year, and it would appear likely that no two areas are enough alike in requirements and objectives to warrant a very formalized procedure to achieve optimal results.

B. Relationships among In- , Through-, and Out-transfers

In-transfers must be seen in the context of and in relationship to the other kinds of transfers discussed earlier in this document. First of all, any external source of new technology is also a potential recipient of technical knowledge from the DARPA-connected user. This is especially the case where highly interactive modes of communication are preferred, such as conferences , computer networks, visitations, and telephone connections. DARPA leans heavily on such modes of contact, perhaps more so than any other branch of government and perhaps more than any other segment of the R&D establishment. However, it tends to restrict such communications to its own existing fraternity, i.e. those universities and firms and military personnel and units who are already involved in DARPA programs. As a result there is a tendency to perceive the existing DARPA network as inclusive of nearly all the important work that is going on and to initiate new programmatic thrusts as bud-offs from other existing DARPA programs. This was most notably the case with Strategic Computing which brings together streams of developments in computer science and engineering which have long been under DARPA's nurturance.

The relationship between in-transfers and out-transfers also suggests the possibility of trading relationships between centers of R&D; one center acquires a new process from a second center in exchange for another process of more or less equal value. Unfortuately, however, there is no obvious way to assign value to new technologies other than through the commercial marketplace so that this kind of barter is not likely to occur in any formal sense. Informally and implicitly, however, a kind of barter assumption pervades academia and also influences DARPA's thinking, especially for programs in their earlier stages.

The trade-off between in-coming and out-going technical knowledge is a very important unresolved issue for DARPA. Its ambivalence arises from its perception that in many areas and particularly in computing it holds a substantial lead over any other sources of expertise throughout the world. Therefore a free and open exchange, while it might be of some benefit, might also give a substantial relative advantage to the trading partner. DARPA clearly has a need to know more about this trade-off question, to know (a) what it should be offering for trade, (b) under what conditions and limitations, (c) to what trading partners, and (d) through what media.

C. Setting aside Resources to Exploit In-transfers

To the extent that in-transfers are important to DARPA it must have unallocated staff and budgetary resources ready to exploit them by beginning new programs. DARPA staff appear to have quite a bit of latitude in this regard in a budgetary sense [although we assume there are limits to this], but it has a very small staff which can be stretched thin keeping track of the existing project portfolio. There is some indication that a recent initiative to bring in new program ideas on a regular basis was not successful because there was no internal staff capacity to accommodate such an influx [see discussion of SRI's "Innovative Search Program" under paragraph #E below].

D. In-transfers within the Network

The largest source of "new" program ideas undoubtedly is the current DARPA project portfolio. DARPA staff keep extremely good track of what is going on within their respective contracts through frequent visitations, and through small technical conferences arranged by themselves or others. The Strategic Computing Initiative was made possible by this kind of tracking, spurred on by a need to move a number of emerging developments into a more advanced prototype form and by the simultaneous perception of an important opportunity to merge separate lines of development for their mutual enhancement as well as to accelerate the development of militarily useful prototypes. The story of "in-transfers" within the network is already largely covered in Part One of this document, since such transfers typically occur by folding an older program into a new one.

E. Domestic In-transfers: Widening the Net

Between roughly 1978 and 1983 DARPA supported an SRI contract to perform "Innovative Search". The project originated through a chance meeting on a commercial air flight between then Director Robert Fossum [1978-81] and a senior executive from SRI. It was subsequently managed by David Petter, assistant to Fossum. The objective was to find innovative items in the commercial sector which could have defense applications. SRI had a very impressive data base already in this area and had run many symposia; therefore, they were offered a sole-source contract for 2 person years per year [$350-400,000 range] to discover new items and bring them to the attention of DARPA officials. Petter had the task of canvassing staff interests and needs.

It was not generally welcomed because it made extra work for everybody, and most perceived that it did not bring items to their attention that enhanced their current program thrusts. It was put under the then director for "Special Projects" but did not thrive there. There was some staff turnover at SRI and some redirection in the last years when they would target 2 or 3 areas per year and run workshops [the successful robotics workshop was one of these]. It was eventually terminated by DARPA because it did not receive enough widespread support from program managers.

One problem with the SRI Innovative Search Project was that it did not fit in with any established part of DARPA's functioning and it seemed to many to be pulling them off in a direction which was not part of their central mission, however worthy it might be. Thus it was an institutional orphan.

Successful in-transfers appear to occur rather informally. An example was of the movement into bio-technology. One staff member [probably at a DARPA staff off-site planning conference] exressed a concern that this was an area of growing importance in which DARPA had no expertise. It was decided [not clear how or by whom] that they would find the best person in this field, hire them as a program manager and give them a starting budget of $2,000,000 to see what they might come up with. In due course, Ira Skirnick was brought on board.

F. Linkage to other Networks: Domestic and Foreign

DARPA staff have a continuing concern to maintain contact with any and all advanced computer developments within this country and around the world. However, it is not always clear how well this is done. Furthermore, we need to know more about how it can be done well, i.e. [1] to maximize the learning of the DARPA community from foreign developments including those occurring within the Soviet bloc, [2] to maximize beneficial sharing among the NATO partners, and [3] to minimize leakage to potential adversaries or innocent third parties through whom adversaries can gain ready access.

Some inter-network connections which deserve study are:

1. Contacts with MCC [see Fischetti, 1983]

Some staff have contacts with this group and several participating firms are also DARPA contractors. There is no indication from interviews that these contacts have been important or that this group has made any special progress beyond what is being done within Strategic Computing.

2. Contacts with the Japanese "fifth generation" computer project supported by MITI [see Buzbee et al., 1982]

Some DARPA staff attended a recent conference in Japan and are tracking MITI developments fairly closely. Key persons in the MITI effort were actually involved earlier in DARPA projects in the U.S. There is some confidence that DARPA-sponsored research is substantially advanced over any other work in the world and that other efforts are at best derivative.

3. European contacts

No European developments are seen as in a league with what DARPA is now doing, but Europeans bid on DARPA contracts and the winning Ada proposal was from a French bidder [see Carlson, 1981], and Europeans are members of ARPANET.

ARPANET appears to have been a very important information support mechanism for more than one later DARPA program [e.g. Ada and MOSIS].

Therefore, it becomes a rather important matter to consider who is on the ARPANET and who is not, how much they use it and for what purposes. There are both ARPANET and the DARPA *network* They are not quite the same thing, but how are they different? What is the trend in membership in each? When people come on, do others go off? What is the foreign representation? What about sub-networks? We know that functional program groups are much smaller clusters, sometimes under 20 real members. What is the pattern of subgroups and what are the super-group patterns?

G. Implications for Type 5 Transfer: Does DARPA Get all the Input it Needs?

Our review of in-transfer presents a very mixed picture with high concern and a strong record of DARPA initiative in some areas, none in others, and seemingly no overall strategy for keeping abreast of new developments outside the Agency's current program portfolio. There are several avenues to explore here including the gathering of better intelligence on what is going on both in the US and in foreign countries including the Soviet bloc, better and more user-friendly document storage and retrieval especially for DARPA program personnel, and more frequent ans systematic efforts to engage in long range plannning.

There is no sure fire way for any R&D organization to know whether it is covering all the bases that should be covered. The next important development in technology may come from a totally unexpected source. It is thus dangerous for an agency like DARPA, charged with the task of making sure there are "no more surprises" [like Sputnik] to be smug about its corner on the high technology market. DARPA officials have a concern about this issue, but they have no coherent strategy to cover many bases. There should be a strategy and that strategy should be as many-pronged as the hand-off strategy. For example there should be:

1. periodic or continuing surveillance of university research and private sector developments to identify promising ideas that might have substantial downstream utility if they were backed by a well-funded R&D effort.

2. periodic brain storming sessions with current DARPA-supported investigators on what new developments might bud off into new programs from their own work or the work of colleagues that they are aware of..

3. systematic review of developments in other countries including the Soviet bloc to determine if there are any avenues they are exploring that we should also follow.

4. a semi-automated knowledge acquisition system to serve all programs and members of the DARPA network. Such a system should be especially accessible to and user-friendly for DARPA program managers, policy advisors, and planners responsible for future work. There is no reason why the current ARPANET cannot include ready on-line access to a very sophisticated full text data base of documents in specified technical areas. DARPA Directors in the past have sometimes been skeptical of the value of information centers, but we believe they were responding to efforts that were of a far more traditional sort. Only a creative approach which is very user-oriented and takes full advantage of state-of-the-art information storage and retrieval technology has a chance of succeeding. For successful models of what is possible and what might be expected in high levels of use, DARPA might turn to the Congressional Research Service.

DARPA might also study possibilities of creating an in-transfer buffer unit. The need is for some person or sub-unit whose job it is to ferret out and advocate new ideas, especially on the risky edge of technology. Such a unit might serve to counteract the inherent conservatism of sticking to the "best people".

Chapter Seven: RECOMMENDATIONS

Overarching these five separate transfer domains there stands a question: does DARPA really care about transfer? Up to now DARPA has never had either an office or an officer of technology transfer nor is any one official assigned such a function as even a part of their role. Indeed, prior to the George Mason University contract of 1984, it had not even asked any contractor to delve seriously into this issue over the 25 year history of the agency. It is partly for these reasons that we feel that many important technology transfer issues receive only sporadic attention. Important technology transfer decisions are made at DARPA all the time, but they are decisions often made on the spur of the moment, typically on the basis of uninformed assumptions. Sometimes they are silent decisions or non-decisions resulting from ignorance or neglect of transfer issues. They are typically made by individual initiative either at the DARPA staff level or the contractor-principal investigator level. This may be fine in many instances; we have noted cases where extraordinarily important transfer took place on such initiatives. What we do not know and have no way of knowing, of course, are the numbers of times that important initiatives were not taken, where opportunities were missed because the people involved did not attend to transfer issues, were not inclined to do so, or felt they had neither mandate nor resources to do so.

There is a real dilemma here when it comes to making recommendations. The logical conclusion from the analysis above might be that there should be more monitoring of what goes on, more staff to specialize on this or that mission [e.g. for each of the five types of transfer], more systematization and documentation of decisions and processes. Yet, it is the leanness and informality of the Agency which are among its most prized assets, features which give it both great efficiency and great flexibility. These features are often pointed to with pride as reasons for past successes. Therefore, it is important to be both judicious and sparing in making suggestions that would have the net effect of increasing formality, bureaucratic control, and staff size. For that reason the list of recommendations presented below should be thought of as a set of possibilities from which only a few might be selected for active follow-up. Even for those that are adopted it should further be stipulated that any change should be made on a tentative basis, implemented for a fixed period of time after which an assessment should be made in terms of net enhancement of the Agency's performance.

Our overriding recommendation is to greatly increase the priority of transfer issues at DARPA. The Assistant Secretary of Defense for D,R &E, the Director of DARPA, and the professional personnel of the Agency should significantly increase their concern for the full range of technology transfer issues covered in this report and seriously consider operational changes based on our findings. This means at the very least, reading the report and meeting to discuss its implications item by item. Past inattention to this area has left the Agency with an unarticulated technology transfer "policy", guided neither by empirical knowledge nor even serious thought. In this policy vacuum many good things have happened in the transfer of knowledge which have strengthened our national security immeasurably. These achievements are to be applauded, but they in no way indicate that the Agency fared better without a policy than it would have if transfer had been seriously attended to. Lack of deliberate and focussed attention to optimizing transfer potential has probably cost us dearly. The loss to the nation from this inadvertence is incalculable and arguably larger than the gain we have experienced from all the R&D programs which we have undertaken.

To begin a more coherent and aggressive approach to transfer issues, we offer five specific recommendations for early action. First, the agency should appoint a *technology transfer facilitator* to oversee the transfer of developed technology into military use. Second, it should develop a state-of-the-art *on-line retrieval system* for tracking data on all projects and proposals. Third, it should develop a new system of program tracking to identify critical stages and outcomes, which we call *transition analysis*. Fourth, it should convene a *panel on access to unclassified technical knowledge*. And, finally, it should establish an annual *forum for the review of nascent technologies*. A brief summary of each of these recommendation follows.

A. The Technology Transfer Facilitator

DARPA should designate a new full time technology transfer facilitator to focus attention on the transfer of DARPA-developed technology to the military services. The military technology hand-off is

DARPA's top priority, and our analysis indicates that it has been poorly managed since the earliest days of the Agency. One person with high energy, seniority, and wide experience in military R&D mangement should be especially recruited to serve in this new role and should be relieved of all other duties. The transfer facilitator would have four areas of responsibility: [1] to make sure that DARPA programs which are reaching maturity transfer smoothly into use or further development by appropriate Services; [2] to track the changing needs and requirements of the Services and to make sure that relevant DARPA staff and programs are cognizant of those needs; [3] to plan and supervise the DARPA briefing process for the Services so that [a] appropriate levels are reached, [b] connections are made among the most knowledgable technical personnel, and [c] all briefings are supported by documentation calibrated to the technical level and "need-to-know" characteristics of the audience; and [4] to monitor and, when necessary, serve as trouble shooter in relations between DARPA staff and Service units responsible for procurement and monitoring of DARPA-sponsored projects.

We do not underestimate the difficulties in establishing such a role. DARPA briefly experimented with something like this in 1981 and 1982, and two individuals operated for a short time in some kind of linking or bridging function. Neither stayed long on the job, one moving to the private sector and the other soon moving on to be a program management officer. It will be important to review this experience carefully to determine what mistakes were made which can be corrected in another try.

Two requirements are clear at the outset, however. First of all, the facilitator should be a special type of person. He should command respect for past achievements, preferably related to transferring technology. He should be very knowledgable about DoD traditions, procurement policies, and R&D management. He should also be someone with a high degree of entrepreneurial skill and energy, willing to take risks, willing to commit himself seriously to the task for at least three years, open to a variety of strategies, able to work at both a policy and a technical level, and not committed to any one technology but able to understand the full range of programmatic effort in the DARPA portfolio. This person should also be able to motivate initiatives by others. The primary task is not to do the transfer but to see to it that others are working on it in ways that will b productive.

The second requirement is that DARPA create the appropriate enabling conditions. The high skill requirements must be matched by salary, a commitment to a three year "experiment", and by an Agency-wide recognition of the role and what it is supposed to do. The facilitator should have full right of participation in technical meetings and briefings and should not be burdened by any responsibilities other than facilitating transfer. He should also be free to experiment with a variety of different strategies and tactics to effect transfer and should have the right to call upon staff to participate in whatever transfer activities are designed.

B. An On-line Retrieval System

DARPA should develop a new state-of-the-art on-line project data base. The importance of MIS is already recognized in a seven-person unit devoted to that function. However, we think it is time for a strong new effort that would serve much more than an accounting function. DARPA should be a leader in capitalizing on recent developments in both I/O and storage capabilities. This new system should allow *full text* searching of past and current proposals and reports. It should allow PMO's to make marginal notes on documents and diary entries on project and program events as they occur. At the same time, such entries should be facilitated by input devices and procedures that minimize the load on PMO's and optimize read-out and display features. Such a system should allow displays of comparative features and outcomes across projects. Expectations that such a system would be of great value not only to DARPA but to the military services in general are enhanced by recent developments in compact laser disc storage capabilities, optical scanner performance [to allow digital storage of all types of reports and documents related to a project] as well as greatly increased sophistication of storage-access software. Such a system would allow much more accurate assessments of the current status of projects and whole programs with a view to identifying critical transition points where DARPA interventions are needed, e.g. to provide more funding, to impose security restrictions, to involve military services or other types of contractors to a greater extent, to convene special meetings, etc.

We strongly believe that the costs of developing such a sophisticated system are fully justified on three grounds: first, such a system is needed by DARPA to compensate for the shortage of personnel available to supervise programs and the inability of the Agency to send representatives to every relevant meeting or to involve itself directly in every key decision made as programs develop. Second, it would be an important and perhaps essential tool to aid the proposed technology transfer facilitator in identifying transfer readiness and potential trouble spots across a diverse set of programs. Third, it would represent a logical extension and appropriate addition to the respected set of programs in "information processing technology" sponsored by DARPA beginning in the early 1960's. The military application potential of such a highly user-friendly and intellectually sophisticated MIS would be exceedingly great.

C. Five Year Transitional Analysis Reporting

DARPA should begin to develop what could be called "transitional analysis reports". These would be reports on project activities in a given program area which highlight three elements: [a] critical transition points in the program; [b] outcomes or achievements as of each point; and [c] transfers that have taken place at or subsequent to that point including transfers within and across DARPA programs, transfers to the military, and transfers which resulted in commercialization. The purpose of such reports is to force an identification and Agency-wide consensus on what constitute "transition points", points at which special consideration should be given to [a] dissemination of findings to a wider or different type of audience, [b] changes in the approach to procurement, [c] stronger links to one or another military service or other DoD unit, and [d] possible controls on the flow of information.

The first such reports would be retrospective, tracing the selected program over a five-year period up to the present. The preparers would begin by assembling a detailed chronology of events that led up to the present status of the program. Using this chronology as the data base, they would then seek to define and identify key transitions, i.e. distinct stages of development together with a listing of outcomes or impacts expected and achieved at each transition.

The first series of reports would necessarily be conducted by a contractor working closely with the appropriate PMO's. One aspect of the contractor's task would be to develop a procedure for documentation which could later be used repeatedly in monitoring program development, a procedure that eventually might be adopted by DARPA staff. The result would be a much stronger insitutional memory and greater Agency-wide consensus and focus on critical transfer issues. The capability to identify and to track development stages of a program in an accurate and timely fashion are the key to good management at DARPA. As these analyses become more sophisticated and as consensus is reached on key variables and their identification, they can be added to the data base for the upgraded on-line MIS discussed above as our second recommendation.

D. Panel on Access to Unclassified Technical Knowledge

The DARPA director should initiate action to establish a panel on access to unclassified technical knowledge. This panel would concern itself *exclusively* with DARPA-sponsored projects and should probably be made up primarily of senior investigators who have been associated with DARPA programs over an extended period. The charge to the panel would include three tasks: [1] to prepare a preliminary DARPA policy statement on the dissemination and/or containment of unclassified knowledge emanating from DARPA projects; [2] to determine what kinds of data should be collected to begin building an empirical base for future containment decisions and policies; and [3] to develop a process for periodic review of the containment issue including possibly the establishment of a standing review committee.

E. The Nascent Technologies Forum

DARPA should institute an annual mini-conference to identify and evaluate new technologies. The purpose would be to seek out areas whose relevance to military or other applications is just beginning to be perceived. These would also be areas that are not currently represented or adequately represented in the DARPA portfolio. A review panel should be composed of leading science administrators, policy makers, and scientists who have a proven track record in identifying important developments at early stages. Ideas for presentations should be solicited from diverse sources inside and outside the government and should be screened and reviewed on a competitive basis to limit presentations to the forum of only concepts with [a] significant downstream application potential, [b] originality, [c] soundness of logic, and [d] soundness of empirical basis. Concepts which are presented should be given full consideration including a written response which specifies follow-on recommendations. The forum would fill a significant gap in DARPA's current modus operandi, namely the in-transfer of new program ideas on a regular basis, taking full advantage of the *national* capacity to generate ideas worthy of DARPA support.

References:

Barber, R. J. & Assocs. *The Advanced Research Projects Agency, 1958-1974*. [prepared by L.W. Huff & R.G. Sharp]. Washington D.C.: Department of Defense Contract No. MDA 903-74-C-0096, Dec. 1975.

Buzbee, B.L., Ewald, R.H., and Worlton, W.J. "Japanese supercomputer technology", *Science*, **218**, 17 December 1982.

Carlson, William E. "Ada: a promising beginning", *Computer*, June 1981, pp. 13-15.

Davis, Dwight B. "Assessing the Strategic Computing Initiative", *High Technology*, April 1985, pp. 41-49.

Defense Advanced Research Projects Agency. *DARPA: 25 years of leadership in military technology 1958-1983*. Arlington, Va.: Defense Advanced Research Projects Agency. 1983[a].

Defense Advanced Research Projects Agency. *Strategic computing. New-generation computing technology: a strategic plan for its development and application to critical problems in defense*. Arlington, VA: Defense Advanced Research Projects Agency, October 1983[b]

Fischetti, M.A. "MCC: an industry response to the Japanese challenge". *IEEE Spectrum*, **20**, No. 11, November, 1983.

Havelock, R. G. *Knowledge containment: a concept paper*. Arlington, Va.: George Mason University Technology Transfer Study Center, 1985.

House Subcommittee on DoD Appropriations. "The Ballistic Missile Program" *Hearings, 85th Congress*, First Session, November 20-21, 1957, p. 7.

Johnson, Elmima C. & Tornatzky, L.G. *Cooperative science: a national study of university and industry researchers [Assessment of the Industry/University Cooperative Research Projects Program (IUCR)]*. Washington, D.C.: National Science Foundation, Division of Industrial Science & Technological Innovation. Draft. June, 1984.

Katz, Barbara and Phillips, Almarin, "The Computer Industry", in Nelson, Richard (ed.) *Government and Technical Progress: A Cross-Industry Analysis*. New York, NY: Pergamon Press, 1983.

Levy, David and Terleckyj, Nestor. *"Trends in Industrial R&D Activities in the U.S., Europe and Japan, 1963-83*. Paper given at National Bureau of Economic Research Conference, August 1985.

Mansfield, Edwin and Wagner, Samuel. Organizational and strategic factors associated with probabilities of success in industrial R&D, *Journal of Business*, **48**, 1975.

National Science Foundation. *Federal funds for research and development and other scientific activities, Fiscal Years 1958, 1959*. NSF 2-58-500 and subsequent volumes of the same publication. Stefik, M. "Strategic computing at DARPA: overview and assessment. *Communications of the ACM*, **28**, No. 7, July 1985.

United Research Incorporated. *A study of Project DEFENDER and the ARPA management process*. October 15, 1962 [cited in Barber Associates, 1975].