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1.0 INTRODUCTION

This Report describes a Study of the Defense Advanced Research Projects Agency's technology transfer process. The Study was performed by the National Security Industrial Association (NSIA) at the request of DARPA. The Study Panel was convened by the Advanced Technology Subcommittee of NSIA's Research and Engineering Committee.

The central focus of the Study was on the particular technology transfer process associated with DARPA's Large Technology Demonstrations which are DARPA's most expensive programs, which are conducted in part for the purpose of technology transfer, and which were perceived to present the area of largest technology transfer challenge to DARPA.

Section 2 of this Report constitutes an Executive Summary of this Study and may be read as a stand alone document. The problem, background and relevant discussions are developed more fully in Section 3. Section 3.4 in particular presents the Panel's conclusions and lists recommendations in priority order and in somewhat more detail than the Executive Summary.

It should be noted that DARPA had, prior to this Study, already taken action towards improvements in certain areas discussed and recommended in this Report. In such cases, the Panel's recommendations should be construed as agreement with those actions. Moreover, we are very pleased that certain additional action is being taken by DARPA along the lines of preliminary recommendations presented in the Panel's Interim Report of April 1985.

NSIA Study Panel was comprised of senior technology-oriented management personnel from industry. The Panel membership was as follows:

MEMBERSHIP	AFFILIATION
Herbert W. Campman, Jr., Chairman	Sanders
Martin C. Blyseth	Grumman Aerospace
Joe H. Brown	Battelle Columbus
Charles A. Hall	Martin Marietta
Richard J. Johnson	Sperry
L. Max Magner	E. I. duPont de Nemours
John J. Mahoney	AVCO
David Passeri	Bendix Aerospace
George Shapiro	Westinghouse Electric
Merle M. Whatley	Texas Instruments

The Methodology for this Study included: study of Technology Transfer barriers and catalysts; interviews with key people inside and outside DARPA; and research relative to previous studies, including Defense Science Board Summer Studies, bearing on the subject of technology transfer as relates to DARPA. Those interviewed represented varying backgrounds and experiences and most were familiar with DARPA's operations and the related technology transfer process.

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During the course of the Study the following people were interviewed:

PERSON INTERVIEWED	CURRENT (OR RELEVANT RECENT) AFFILIATION
Mr. William S. Aiken, Jr.	Director for Aeronautics NASA Washington, DC
Col. James Allburn, USAF	DARPA 1400 Wilson Blvd. Arlington, VA
Mr. Norman R. Augustine	Sr. Vice Pres., Information Systems Martin Marietta Corp. 6801 Rockledge Drive Bethesda, MD
Mr. William F. Baird	TRW
Mr. Carl T. Bayer	Professional Staff Member House Armed Services Committee
Mr. Gerald Cann	Prin. Deputy Asst. Secretary, Navy (RE&S)
Dr. Robert S. Cooper	Director, DARPA ASD (Res. & Tech.) 1400 Wilson Blvd. Washington, DC
Mr. John N. Entzminger	Director of Tactical Technology DARPA 1400 Wilson Blvd. Washington, DC

PERSON INTERVIEWED	CURRENT (OR RELEVANT RECENT) AFFILIATION
Dr. William C. Eppers	Acting Director Avionics Lab Air Force Wright Aeronautical Labs
Dr. Herbert Fedehren	IDA
Mr. Charles A. Fowler	Senior Vice President MITRE Corporation Burlington Road Bedford, MA
Dr. Edward T. Gerry	President W. J. Schafer Assoc., Inc.
Mr. Roy V. Harris, Jr.	Director for Aeronautics NASA Langley Research Center M.S. 116 Hampton, VA
Dr. George H. Heilmeier	Sr. Vice President & Chief Technical Officer Corp. Research, Development & Engineering Texas Instruments, Inc.
Adm. Isaac C. Kidd, Jr., USN (Ret.)	Private Consultant
Dr. Bernard A. Kulp	Chief Scientist Director of Labs, AFSC
Maj. Gen. Donald L. Lamberson	Asst. DCS/Research, Development & Acquisition HDQTRS. USAF/RD Washington, DC
Mr. Donald J. Looft	Vice President Magnavox Government & Industrial Electronics Co.

PERSON INTERVIEWED	CURRENT (OR RELEVANT RECENT) AFFILIATION
Mr. Verne L. Lynn	Deputy Director for Technology DARPA 1400 Wilson Blvd. Washington, DC
R.Adm. J. T. Parker	Deputy Director Office of Research, Development, Test & Evaluation Dept. of the Navy
Gen. Alton D. Slay (Ret'd)	President Slay Enterprises, Inc. (ex Commander, AFSC)
Dr. James A. Tegnelia	Asst. Under Secretary of Defense Conventional Initiatives

The Panel wishes to thank DARPA personnel for their invaluable cooperation and willingness to expose their thoughts, and occasionally frustrations, in a very candid manner. Special thanks are due Mr. Verne L. Lynn at DARPA who initiated the request for this Study and whose patience and assistance were key factors throughout its course.

2.0 EXECUTIVE SUMMARY

2.1 GENERAL

This is a Report of a study of DARPA's Technology Transfer process. It includes recommendations for improvement of that process.

The NSIA/Research and Engineering Committee DARPA Technology Transfer Study Panel was formed in 1984 at the request of DARPA.

The methodology encouraged by DARPA and employed by the Panel was to study the technology transfer barriers and catalysts and research the Technology Transfer Process as viewed by DARPA itself and as viewed by others, including past studies (DSB Summer Studies, etc.) bearing on the subject. The Panel considered analogous technology problems experienced within industry. With suggestions and help from DARPA, the Panel also conducted individual and group interviews with selected people from: OSD; the Services (both active and retired); present and past DARPA Management; Congressional Staff; and other Agencies. The Panel's emphasis in selection of people interviewed was on obtaining a variety of perspectives representing a wide spectrum of knowledgeable views of the DARPA Tech Transfer process. Effort was made to seek views from different vantage points and varying backgrounds and experiences.

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Differences between the role of DARPA contrasted with that of the Services and other Agencies make smooth technology transfer to the Services/Agencies a difficult process, particularly as regards the Large Technology Demonstrations. Such efforts are both expensive and of great potential importance to the Services. It is fundamental that the Services/Agencies are the ultimate procurers of material resulting from the successful DARPA initiatives. Hence, an optimal system for technology transfer, one which is comfortable both to DARPA and the Services/Agencies is of great importance to the nation.

DARPA's role and philosophy can be broadly characterized as:

- Opportunity Driven,
- Creative New Concepts,
- Bold New Initiatives,
- Order of Magnitude Leaps Forward, and
- Revolutionary Breakthroughs.

On the other hand, the Services' role and philosophy can be broadly characterized as:

- Need Driven,
- Near Term Urgencies,
- Identified Missions
- Careful (Smaller) Steps with Minimum Risk
- System Life Cycle Cost Effectiveness and
- Orderly Phasing of Evolutionary Technology Advancements.

These fundamental differences make it readily understandable that barriers arise to inhibit timely smooth transfer of technology from DARPA to the Services. (EDC)

In the course of its study, certain concerns, opinions and impressions emerged which relate to the technology transfer subject. Some of these expressed opinions are contained in section 3 of this Report.

Further during the course of the Panel's research, the search for a key causal nature of the tech transfer problem tended to converge on the basic feeling of many interviewed that there is not adequate communication between DARPA and the Services, that the communication which does exist does not start early enough in the planning of Large Tech Demos, and is often not truly two-way communication, i.e., that the Services cannot adequately input their views prior to the outset of these large and potentially far-reaching tech demos. It was to these causal areas that the Panel subsequently devoted much of its study and effort.

2.2 PERCEPTIONS REGARDING DARPA'S ROLE

It is impossible to discuss DARPA's large technology demonstrations and the related technology transfer process without considering DARPA's role.

It is assumed that the reader of this Executive Summary is already familiar with DARPA's broad role in the nation's technology-oriented defense posture, since this is critical to understanding why DARPA performs Large Technology Demonstrations and the related technology transfer process. If not, it is suggested that the reader review section 3.2.

Briefly however, DARPA started as a small center of technical excellence in response to a perceived National weakness in science and technology. "Cutting edge technology" was and remains the keystone. In order to demonstrate the advanced technology and prove concepts for potential operational use, however, over the years DARPA also became involved in Large Technology Demonstrations which represent heavy dollar investments and which, even though aimed in part toward technology transfer, are thought by many to present a formidable technology transfer challenge.

DARPA's priorities and emphasis have changed at times over its life but have generally been founded on a fairly consistent self-image including, for example, no vested interest in the status quo, no encumbrance of existing Roles and Missions, high-risk/high-payoff ("10 dB solutions"), and an underlying technical superiority.

In the course of investigation by the Panel it became clear that in the near-unanimous opinion of the people interviewed, DARPA is essential to the nation and the DoD, and is virtually the only agency able to initiate and successfully prosecute the bold technology breakthroughs which are vital to the nation's security. It is felt, however, that in the particular area of large and expensive technology demonstrations, especially in the systems areas, certain changes could be effected which will further improve the DARPA-to-Service technology transfer process.

As regards DARPA's other activities, virtually all interviewed agreed that DARPA's role should continue to include the traditional smaller technology investigations (6.1 and 6.2 funding), and most felt that there was not a serious technology transfer problem in those areas.

2.3 THE TECHNOLOGY TRANSFER PROCESS/CHALLENGE AT DARPA

It should be stated here that although there are wide ranging differences in opinion as to the degree of DARPA's success in technology transfer, the Panel believes that the problems associated with technology transfer transcend DARPA in particular, are universal in nature, and generic to all organizations which develop new technology. Relative to DARPA's particular transfer process, although several specific programs were studied for their value re insight to the transfer process, the Panel was more concerned with the way in which technology transfer is addressed and how it could be improved to optimize the chances of a successful transition, as opposed to passing judgement on specific case histories.

The perception of some at DARPA appears to be that fairly informal ad hoc procedures are appropriate for their type of development, where every program is different and thus no "standard" operating mode is appropriate. There is heavy emphasis on good people and belief that with the right Director, Deputy Directors, and other DARPA personnel, the programs will be relevant and will be coupled to the Services/Agencies early.

It is the Panel's position that, although good people and good managers are often more effective than even the best formal procedures, DARPA's present procedures are simply too reliant on individual characteristics, especially given the relatively short tenure, selection criteria and varied backgrounds and strengths of DARPA personnel over a period of time.

The need for continued free-thinking technology and technical opportunism at DARPA is clear. In the opinion of many, however, DARPA is often too insensitive or unaware regarding the needs and problems of the Services. The Panel feels that an increase in awareness and sensitivity to the Services needs and problems need not destroy DARPA's essential free thinking. This increased awareness of needs and problems may in fact enhance DARPA's creative perspectives and will generally aid the technology transfer process.

After much discussion and based on the largest area of concern, the Panel primarily focussed on the technology transfer process associated with Large Technology Demonstration Programs. As previously stated, it is recognized that these large demonstrations are conducted in part for the very purpose of paving the way toward smooth technology transfer. Nevertheless, it is widely felt, and acknowledged by DARPA itself, that improvement in this area would be very desirable.

The Panel considered a number of barriers and catalysts to Technology Transfer which fell into several categories (see sections 3.3.4.2 and 3.3.4.3).

Some DARPA programs which were perceived as successfully transferring were found to have employed a hand-off approach which DARPA has recently been using. (This approach is referred to in section 3 of this Report as a "Hybrid" approach.) Typically, such a DARPA new-start has Service/Agency connection from the beginning of the technology feasibility phase. Although DARPA funds most or all of the technology phase, Service/Agency commitment is established by means of an agreement reached among the parties prior to

program start and, in some cases, some funding contribution. The agreement provides for increasing Service/Agency share of funding as the program passes through the concept demonstration phase as well as providing the plans for transition of management from DARPA to the Service/Agency.

This more recent approach appears to have the potential for improving DARPA's coupling to users and, thereby, improving chances of transitioning technology to the Services/Agencies. There are difficulties in implementing even this approach however. The challenges in negotiating the agreement and in the subsequent management of the programs are considerable. In some ways such programs are similar to large Joint Service Programs, which are often prone to problems.

It should be stated here that notwithstanding the desirability to improve the technology transfer process, the Panel recognizes that on rare occasions special circumstances may dictate the continuance of a DARPA initiative even where successful technology transfer has not occurred in spite of the best efforts of all. Such circumstances are further discussed in section 3.3.4.5.

2.4 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The Panel has concluded that a principal driver of a successful transition is a close supplier/user relationship (DARPA/Service) that is promoted and encouraged throughout the life cycle of a given technology opportunity, namely, from selection through transition.

The Panel feels strongly, based on its study, that its recommendations, if followed, can result in real and substantial improvement to DARPA's technology transfer process in the area of Large Technology Demonstrations. This will be achieved through better and more participatory planning and an improved partnership with the user Services/Agencies. We further believe these improvements can be implemented without undermining the very necessary and desirable freedom of DARPA to act boldly with the advanced technology thrusts which are of high importance to the Nation's defense posture.

These recommendations, outlined below, are more fully discussed in section 3.4 of this Report. Additionally, section 3.5 discusses advantages and some possible concerns relative to the recommendations.

Based on the Panel's review of DARPA's technology transfer process in general, but with major focus upon the principal problem area of Large Technology Feasibility Demonstrations, the following is a summary of the Panel's specific recommendations aimed at improvement of the technology transfer process:

- New Agency Issue

  Some prior DSB studies and certain others have recommended that a new Agency should be created to perform the Large Technology Demonstrations. This Panel recommends against creation of such a new Agency. The establishment of yet another Agency would only add another layer of bureaucracy, reduce DARPA's flexibility, and simply move the technology transfer problem to the new Agency.

- Advisory Board

An Advisory Board should be formed to review the proposed large technology demonstrations before-the-fact. This Board should be composed of both OSD and senior Service people. It should not be given the power to commit or veto DARPA programs. The principal purpose of this Advisory Board will be to ensure that during the initiation phase of major technology feasibility demonstrations there is an early and open two-way forum for communication of plans, potential user comment, and preparatory actions for life-cycle participation. The essential functions of this Board would be as follows:

- Learn about DARPA-proposed concept demonstrations early-on.
- Offer user's perspective to DARPA's concept demos early-on.
- Where appropriate, suggest synergistic possibilities with other lab technologies.
- Advise/suggest as to an optimum process for tech transfer of particular programs into the system.
- Where appropriate, assist in planning for and expediting tech transfer of a particular concept.
- Make suggestions/recommendations to DARPA as to who should manage particular Large Technology Demonstrations.
- Offer DARPA thoughts as to other candidate areas needing future breakthroughs (iterative exchange of ideas).
- Give potential users advanced awareness as to possible future availability of technology from DARPA.

The Panel also considered the related questions of which of DARPA's many programs should utilize this Advisory Board and when it should meet. That discussion is contained in section 3.4.2.1 of this Report.

- Service Management

DARPA should continue its very worthwhile efforts toward achieving a situation whereby the user Service/Agency will truly manage certain large demo programs. In the ideal case, the Service/Agency would provide day-to-day technical direction in addition to the current procurement and administrative functions, while the DARPA technologists would serve as technical advisors, with significant technological authority vested in DARPA. However, notwithstanding Service Management, DARPA must in many cases continue to fence the majority of the necessary 6.3A funds as they are often better able to do so than the Services.

- Personnel and Organizational Issues

  - DARPA's stated criteria for seeking and hiring of people is based on the following criteria, in priority order:

    1. Technical Strengths
    2. Entrepreneurial Strengths
    3. Management Strengths

    Given the special nature of DARPA, these are appropriate criteria, assuming that day to day management of Large Tech Demos is turned over to the user Services/Agencies.

  - The relatively short tenure of DARPA personnel (approximately 3-year half life is stated) is probably appropriate to ensure a flow of creative people at DARPA, but this poses some concern relative to the somewhat countervailing need for continuity on programs.

  - On another issue, that of the overall size of DARPA's professional staff there is somewhat of a dilemma. On the one hand large additions to DARPA's staff are not desirable given the special character of its operation. However, the oft-stated high number of contracts per cognizant program manager (up to 15 or more in some cases) is felt by many to be excessive for any reasonable expectation of adequate cognizance and management. DARPA should re-look its manpower resources and attempt to reduce this to a more manageable level through reduction or combining of programs/contracts and/or (minimal) staff increases. Major growth of DARPA should be avoided, however.

- Selection of Programs

  With regard to the selection of programs for Large Technology Feasibility Demonstrations, the Panel recommends that DARPA's selection process should include, for background purposes, greater use of Service inputs and ROC's, SON's, relevant DSB studies, etc. These documents may not often generate program ideas directly but will give DARPA personnel an improved feel for areas of significant need, provide a basis for extrapolation, and thus form a contextual background for some of DARPA's bold creative thinking:

  Further relative to program selection, the Panel recommends consistent (albeit informal) use of a "catechism" similar to that outlined in the 1981 DSB Summer Study as a useful test/discipline at the outset. The catechism is simply a short list of fundamental questions, outlined below:

  - What is it? What is this effort trying to accomplish? (defining the technology sufficiently well to discriminate it from other similar technologies)

- Why is it important? Assuming success, what differences can it make to the user or in a mission area context? (taking into account the nature and limitation of current practice)

- What is the current status? What is the DoD program? What should it be? What is new about the proposed effort and why will this approach be successful?

- How long will it take? How much will it cost? What are the measures of success?

- Technology Transfer Initiative

Technology transfer strategies should be a major concern of the Director, Deputy Directors, and all Program Managers at DARPA. A technology transfer plan should in itself be a required initiative for DARPA especially on all Large Technology Demonstrations. To this end, the Panel recommends:

- DARPA should establish and make available to all Program Managers a central historical data base or "corporate memory" of successful technology transfer strategies based on actual program experience. This resource, which should also record unsuccessful experience, should be utilized by Program Managers when planning and embarking on a new program, as a guideline to assist in developing an appropriate technology transfer plan.

- A new office within DARPA might be established to generate and maintain this experience-data bank/strategy guideline. This is not recommended however, providing the task can be accomplished within DARPA's current organizational framework.

- DARPA technology transfer strategies should span all aspects of the technology opportunity life cycle from selection through transition and/or insertion. This is a very difficult process, but the results should be well worth the effort in promoting smooth and rapid technology transfer.

3.0 THE STUDY

3.1 PROBLEM STATEMENT

Differences between the mission and basic nature of DARPA versus those of the Services and other Agencies make smooth technology transfer to the Services/Agencies a difficult process, particularly in regards to the Large Technology Demonstrations. Such efforts are both expensive and of great potential importance to the Services. It is fundamental that the Services/Agencies are the ultimate procurers of material resulting from the successful DARPA initiatives. Hence, some optimum system for technology transfer, one which is comfortable both to DARPA and the Services/Agencies is of great importance to the nation.

To put this into perspective, the basic problem of technology transfer is inherent in all situations where technology is created in an R&D environment and must transition to production and the user environment. Technology transfer in any organization is a difficult process. This is due to a variety of differences between the technology developer and the user. These differences include lack of a common goal, mismatches in time horizon of interest, risk preference, and often lack of agreement on the appropriateness and suitability of the technology to be transferred. In the private sector, numerous studies have shown that the technology transfer process is most efficient when it is responsive to a clear market need, ("market pull") and is an integral part of an overall planning process geared to produce new products on a regular basis. Conversely, the process is least efficient when the technology development is decoupled from ultimate market, and is not anticipated or planned for by the organization that it is to serve ("technology push").

Relative to the technology transfer process under study, the transfer of DARPA's technology to the Services, it should be observed there are fundamental differences between DARPA and the Services. DARPA's very important role and operational philosophy can be in part characterized by the following descriptors:

- Opportunity Driven
- Creative New Concepts
- Bold New Initiatives
- Order of Magnitude Leaps Forward
- Revolutionary Breakthroughs

The Services on the other hand, with their essential and traditional role and in view of many practical and necessary constraints, can be principally characterized by a different set of descriptors:

- Need Driven
- Near Term Urgencies
- Identified Missions
- Careful (Smaller) Steps with Minimum Risk
- System Life Cycle Cost Effectiveness
- Orderly Phasing of Evolutionary Technology Advancements

These fundamental differences make it readily understandable that barriers arise to inhibit timely smooth transfer of technology from DARPA to

the Services. Some of these tech transfer barriers have been articulated by DARPA itself (Ref. 1). They fall into two groups. DARPA sees the first set of barriers as fundamental, also often existent within the Services themselves as technology moves from the Services' own labs to the operational forces. These are:

- Perception of competition with 6.4 developments
- The "mysteriously disappearing" 6.3A budgets *
- High costs of the next RDT&E phase
- Competing approaches to similar problems
- Lots of "blackball" potential (many can stop, only all can make go)

DARPA goes on to state that in the particular case of tech transfer between DARPA and the Services there are still other barriers which are:

- No Service "Corporate Commitment"
- Competition with Service Lab ideas
- Revolutionary approaches don't fit the Services' system

The Study Panel, with DARPA's encouragement, held many discussions with Service and ex-Service people; with DARPA and ex-DARPA people; with people from other Agencies; with OSD; and with Congressional Staff people, relative to the technology transfer problem. In the course of these discussions, certain other concerns, opinions and impressions emerged which relate to the technology transfer subject. Some of these expressed opinions were:

- DARPA is not and cannot be expected to be expert in the business of war-planning.

- DARPA by its very nature does not have high understanding or appreciation of the needs or operational modes of the Military Services.

- The risk of failure with DARPA's advanced programs will be higher than the Services like to take (with general agreement, however, that this <u>should</u> be so and, in fact, a desire that DARPA continue on its bold course).

- The Services/Agencies cannot always adequately fence 6.3A monies to complete bold technology demonstrations commitments. DARPA seems to be better at this.

- There is a fundamental dilemma whereby the Services would be more comfortable with a full analysis of military impact, but until a demonstration gathers data, it is difficult or impossible to conduct a credible detailed impact analysis.

Thus, overall there is an understandable basis for the Technology Transfer Problem which exists between DARPA and the Services and other potential user Agencies, analogous in some respects to problems experienced in industry.

* (wherein the Services' 6.3A funds too often are turned over to the more <u>urgent</u> needs of the Services, in spite of the totally recognized <u>importance</u> of the planned 6.3A programs)

During the course of the Panel's research, the search for a key causal nature of the tech transfer problem tended to converge on the basic feeling of many interviewed and the Panel that there is not adequate communication between DARPA and the Services, that the communication which does exist does not start early enough in the planning of large tech demos, and is not truly two-way communication, i.e., that the Services cannot adequately input their views prior to the outset of these large and potentially far-reaching tech demos, even though the intent of those demos in part concerns technology transfer.

It was to this causal area and means to improve same that the Panel subsequently devoted much of its study and effort. Again we should state the principal emphasis of this study was on the larger technology demonstrations, particularly of a systems nature. Opinion was virtually unanimous that this is where the principal challenge lies.

In the sections which follow we will review DARPA's role; DARPA's current procedures; and various related issues, all principally in context with the technology transfer process. Discussion of these and other issues is contained in sections 3.2 and 3.3 and the Panel's conclusions and recommendations are presented in section 3.4, with some additional commentary regarding those recommendations included in section 3.5.

3.2 DARPA'S ROLE IN GENERAL

It is impossible to discuss DARPA's large technology demonstrations and the related technology transfer process without considering DARPA's role.

The current role of DARPA as well as its operating mode have evolved over the 25+ years of its existence and have been heavily influenced by the original motivations and charter as well as the personalities and characteristics of its staff and Directors over that period. Throughout its fact-finding activities the Panel encountered substantial evidence of DARPA's being perceived as having unique characteristics, missions, modus operandi, etc. These perceptions appeared in both positive and negative aspects, for example, from "elite" to "arrogant". Even those in the latter category, however, were generally accompanied by additional comments of a positive nature.

DARPA's priorities and emphasis have changed at times over its life but have generally been founded on a fairly consistent self-image including, for example, no vested interest in the status quo, no encumbrance of existing Roles and Missions, high-risk/high-payoff ("10 dB solutions"), and an underlying technical superiority.

DARPA started as a small center of technical excellence in response to a perceived National weakness in science and technology. "Cutting edge technology" was the keystone. Today DARPA is also involved in major System Feasibility Demos which although performed in the interest of achieved technology transfer, nevertheless are thought by many to present a serious technology transfer challenge wherein considerable improvement is needed.

DARPA (or ARPA as it was then known) was formed in 1958 shortly after Soviet's launch of Sputnik, a major technological surprise and shock to the United States. Secretary of Defense McElroy was instrumental in creating a

Government Agency, one with a small but elite technical staff. This staff was not permanent or institutional, but was drawn from the best in industry, academia and Government and for relatively short (3-5 years) tours of duty. DARPA had no organic contracting arm but rather did business through the contracting operations of various Services/Agencies. These unusual but important aspects remain essentially unchanged today.

DARPA operations reflected the unique aspects of the organization, e.g.,

- High-Risk/High-Payoff
- Non-duplicative to developments of the Services/Agencies
- Multi-Service applications
- Very bold R&D
- Important missions sometimes assigned by the Secretary of Defense

Emphasis from DARPA's origin has been on preventing technological surprise and ensuring that important opportunities were not overlooked just because they didn't clearly fall under anyone's charter.

DARPA's early activities were, not surprisingly, directed in large part toward space: Launch Vehicles, Military Satellites, Space Technology, BMD, Nuclear event detection, etc. It is noteworthy that, in this era, many of these space related activities were in fact large-scale technology demonstrations, a concept which would re-emerge in the 1975-85 timeframe.

DARPA's evolution in the mid-1960's and later was driven significantly by the Viet Nam War, e.g., battlefield sensors, weapons, unattended ground sensors, etc. Also significant were strategic thrusts such as anti-submarine warfare and space object tracking. The principal trend up to the mid-1970's was toward technology base development, i.e., a philosophy of "focus on the technology, let the systems take care of themselves". Therefore, few large scale technology demonstrations were conducted.

A significant shift in DARPA's operational mode occurred in the mid-seventies. There had been a large number of smaller programs, technology developments, etc. A basic change was made in DARPA's direction, eliminating some small programs and putting others under a few umbrellas tied to major thrusts. These few major thrusts, had the potential to make a decisive (10dB) difference in the outcome of combat. A number of Large Technology Demonstrations (LTDs) were undertaken in the subsequent years, ranging up to several $100M per demonstration. This emphasis remains at DARPA today.

Given this emphasis on Large Technology Demonstrations at DARPA, the technology transfer process and the role of DARPA became further intertwined. Therefore, any recommendations concerning technology transfer and DARPA can only be meaningfully made given a valid baseline understanding of DARPA's primary mission and roles. DARPA is generally considered the nation's principal organization chartered to deal with 1) the opportunities which new or higher risk technologies offer 2) the pursuit of technologies which make a difference in "the way in which wars are fought and won," and 3) related feasibility demonstrations, often requiring multi-Service participation or involving cross-Service mission areas. Observing that projects such as ABM, STEALTH, Directed Energy/SDI, Blue Laser, etc. are among the more important success models for DARPA, then a macro view of DARPA would be that of: a home for an umbrella of highly inter-related advanced technologies often

involving cross-Service mission areas, occasionally requiring substantial efforts for demonstration of military worth.

In the course of investigation by the Panel it became clear that in the near-unanimous opinion of the many people interviewed, DARPA is essential to the nation and the DoD, and is virtually the only agency able to initiate and successfully prosecute the bold technology breakthroughs which are vital to the nation's security. Moreover, virtually all feel strongly that DARPA's focus should remain on the bolder, high-potential payoff, (and often high risk) programs not generally undertaken by the Services or other Agencies. It is felt, however, that in the particular area of large and expensive technology demonstrations, especially in the systems areas, certain changes should be made aimed at improvement of the DARPA-to-Service technology transfer process. These recommended changes are discussed later in this report.

As regards DARPA's other activities, virtually all interviewed agree that DARPA's role should continue to include the traditional smaller technology investigations (6.1 and 6.2 funding), and it was widely felt that there was not a serious technology transfer problem in those areas, principally because the technology will, failing all other means, transfer by diffusion as defined later in section 3.3.4.1.

3.3 DARPA AND TECHNOLOGY TRANSFER CONSIDERATIONS

3.3.1 BACKGROUND

As part of its efforts the Panel reviewed documents representing studies which had come to grips with the technology transfer issues in varying degree in recent years. One of these was the Defense Science Board Summer Study of 1981 (Ref. 2) which addressed "innovation" and "technology transition" from the broad DoD perspective. That report included a section specifically addressing DARPA which was particularly critical of its operation including aspects directly related to technology transfer (DSB, 1981, Section VI, Part C).

Although there are wide ranging differences in opinion as to the degree of DARPA's success in technology transfer, the Panel believes the problems associated with technology transfer transcend DARPA in particular, are universal in nature, and generic to all organizations which develop new technology. Relative to DARPA's problems, although several specific programs were studied for their value regarding insight to the technology transfer process, the Panel was more concerned with the way in which technology transfer is addressed and how it could be improved to optimize the chances of a successful transition, as opposed to passing judgement on specific case histories.

3.3.2 PRIOR RECOMMENDATIONS OF OTHERS

Several studies have proposed alternatives to the current practice, usually including increased emphasis on Services/Agencies/users involvement and funding.

A specific question addressed by the 1981 DSB Summer Study was "Is the process of transition from technology base to weapons systems adequate?". The Defense Science Board study addressed the attributes of the transition

process, barriers to transition, and the characteristics of a successful transition. Although the DSB viewed the problem from the broader perspective of OSD/USDRE and the total technology base, they also considered DARPA's role and problems in particular.

A principal recommendation of the DSB in the area of technology transition was the creation of an "Advanced Projects Agency" (i.e. a new agency or program management office) staffed by people in the services, to manage the technology demonstration and to conduct "test marketing" experiments. This alternative solution, proposed by DSB Study 81, DSB 82, and others, (Ref. 2,3&4) would be a new agency charged with taking DARPA technology into demonstrations suitable for Service/Agency evaluation. This agency would cut across all of DoD (and presumably others such as NSA) and be funded by Congress or by a tax on each service. This subject will be discussed later in this Report relative to the Panel's recommendations. Some other noteworthy comments from the DSB '81 Summer Study are listed below:

- "USORE (should) direct the Services to review DARPA programs over $30M for potential military applications, operational needs and transition plans." (p. ix)

- "After reviewing the technology base planning strategies employed by the Services and DARPA, it was found that there was no consistent DoD wide linkage between investment strategies and the requirements of future combat." (p. i-2)

- "In the case of DARPA:

  - The growth in the DARPA technology base program has greatly exceeded the capability of the staff to properly execute the programs."

  - "There appears to be no comprehensive filtering of DARPA program versus on-going Service efforts and the DARPA results are not widely disseminated and therefore not sufficiently critiqued." (pp. i-6&7)

These observations, made by the Defense Science Board in their broader Technology Base Study of 1981, are remarkably similar to the positions taken by many of those interviewed by this Panel in the 1984/85 time frame. Further, most of the latter group had not participated in the 1981 DSB effort.

In response to a recommendation of the Hermann report (Ref. 5) related to critical technology demonstrations, USDRE established (Ref. 4) a committee (Millburn Committee) chaired by Dr. Edith W. Martin. The principal recommendations under consideration by the committee were to establish 1) a separate new program element in the budget controlled by the USDRE and 2) an OSD level executive committee (Committee on Critical Technology Demonstration - CCTD) to pass judgment on program selection, to approve broad plans, and to allocate resources. The committee was made up of personnel from both the service and DoD agencies. This committee apparently ceased to exist prior to having reached final consensus. Some of the discussions and arguments used or collected during the course of that study are nevertheless pertinent and thus have been factored into this Report.

In analyzing the overall technology transfer process, its attributes, barriers, and catalysts, this Panel found itself in substantial agreement with many points made in prior study efforts. However, the conclusions and recommendations of this study, having specifically focussed on the DARPA environment, are conceptually and structurally somewhat different from those addressed by the prior studies.

3.3.3 RELEVANT DARPA OPERATIONAL PERSPECTIVES

3.3.3.1 GENERAL

With its culture and history as described earlier, DARPA continues to be a unique agency with a self-image as "technological opportunists". DARPA maintains a small staff of about 100 technical professionals. The primary attribute for staff is technical excellence.

DARPA draws its ideas for new programs from many sources, e.g. internal professionals, Services and other agencies, academia and industry. Many of these concepts do not result from a formal requirement or planning process, long-term road maps, user inputs, etc. The lack of a formal front-end process involving the Services/Agencies obviously presents some risk of DARPA's not solving the right problems. There is, in fact, a general perception that DARPA is too loosely coupled to the real operational world and that consequently there is insufficient useful transfer from DARPA to the users and little impact on DARPA by user needs. Nevertheless, there can be found examples of successful coupling both early and throughout programs via informal channels, e.g., cases of interaction at all levels between DARPA personnel and their counterparts in the Services/Agencies.

The perception of some at DARPA seems to be that the informal ad hoc procedures are appropriate for their type of development, where every program is different and thus no "standard" operating mode is possible. There is heavy emphasis on good people and belief that with the right Director, Deputy Directors, and other DARPA personnel, the programs will be relevant and will be coupled to the Services/Agencies early. Likewise, some at DARPA seem to feel that additional procedures, regulations, etc., probably wouldn't help much and might interfere with DARPA's traditionally free operating style.

The need for continued free-thinking technology and technical opportunism at DARPA is clear. This operational mode is a key part of DARPA's essential role and the value of this to the nation cannot be overstated. In the opinion of many, however, DARPA is often insensitive or unaware regarding the needs and problems of the Services. The Panel feels that an increase in awareness and sensitivity to the Services needs and problems need not destroy DARPA's essential free thinking. This increased awareness of needs and problems may in fact enhance DARPA's creative perspectives.

3.3.3.2 SELECTION OF PROGRAMS

With regard to the actual selection process, the Panel feels that in addition to using the idea-sources described in the previous section, the selection process should include, for background purposes, review of ROC's, SON's, Service/Agency plans, relevant DSB studies, intelligence inputs, etc. and discussions with their originators if/as appropriate. However, since

ROC's and SON's, etc. are not generated in an ideal universe they are usually a compromise between what is needed and what is thought to be feasible. Therefore, they will generally not demand or envision the quantum step improvements that DARPA's charter envisions. Thus such documents may not generate program ideas directly applicable but will, more likely, give the DARPA personnel a feeling for areas of significant need, a platform for extrapolation, thus forming a contextual background for DARPA's bold creative thinking.

The Panel also feels that this improved perspective on DARPA's part will frequently aid in the transferability of those ideas because of the implied closer ties to Services' own perceptions of their long-term needs.

Further, in a manner which does not unduly inhibit the free thinking of DARPA, the Panel recommends the consistent (albeit informal) use of a "catechism" similar to that outlined in the 1981 DSB Summer Study (Ref. 2) as a simple test which could aid in DARPA in its perspective at the time of initial inception of the larger tech demos. Specifically, that Study recommends the fundamental discipline of asking the following types of questions at the outset of a new initiative:

- What is it? What is this effort trying to accomplish? (defining the technology sufficiently well to discriminate it from other similar technologies)

- Why is it important? Assuming success, what differences can it make to the user or in a mission area context? (taking into account the nature and limitation of current practice)

- What is the current status? What is the DoD program? What should it be? What is new about the proposed effort and why will this approach be successful?

- How long will it take? How much will it cost? What are the measures of success?

An additional question which should be raised at the time a program is selected is what other ancillary developments may be required, and on what time scale, to enable the primary program to be implemented. Such related enabling technologies might require a technological breakthrough in themselves. Failure to address such ancillary developments in an appropriate time frame may result in delays or total barriers to the technology transferability of the primary program. Examples might include a cryogenic cooler meeting specific physical constraints, changes in training or doctrine, or, to take an example from pre-DARPA history, an aircraft (B-29) capable of carrying an atomic bomb a considerable distance.

3.3.3.3 PERSONNEL AND ORGANIZATIONAL ISSUES WITHIN DARPA

An important element of DARPA's special character and success is its philosophy relative to selection and retention of technical people. DARPA has stated their criteria for seeking and hiring new people generally involves focus on the following attributes in the priority order given below:

1. Technical Strengths

2. Entrepreneurial Strengths

3. Management Strengths

The Panel feels that, given the special nature of DARPA, these are indeed appropriate criteria and priority rankings. This assumes, however, the day-to-day management of the Large Tech Demos is turned over to other Agencies as recommended elsewhere in this report.

As regards the issue of the relatively short personnel tenures at DARPA (approximately 3 years half-life is stated by DARPA), we would offer the following comment:

- The general desirability of a flow of new creative people is recognized.

- Strategies relative to technology transfer based on successful past experience at DARPA should be made available to Program Managers. (This is discussed in section 3.4.2.2).

- Personnel rotation, properly practiced, can also aid the Tech Transfer process.

Relative to yet another issue, that of the overall size of DARPA's professional staff versus its workload, there appears to be a dilemma. On the one hand it is generally felt large additions to DARPA's staff would not be desirable and indeed might unfavorably alter the special character of its operation. On the other hand many interviewed expressed the strong feeling the oft-stated high number of contracts per cognizant program manager (up to 15 or more) was entirely too high for any reasonable expectation of adequate cognizance and management. The Panel concurs with this latter feeling and recommends that DARPA re-look their manpower resources vs contracts undertaken and make an effort to reduce this to a more manageable level through some combination of reductions in total number of programs/contracts, appropriate combining of programs and perhaps some slight increase in staff where appropriate, as well as greater use of Service/Agency personnel. However, major growth of DARPA staff in the area of large program management capability should be avoided and DARPA should continue to push toward the Services taking more of that load.

Although good people and good managers are often more effective than even the best formal procedures, the Panel feels that DARPA's present technology transfer strategies and procedures are simply too reliant on individual characteristics, especially given the relatively short tenure, selection criteria and varied backgrounds and strengths of DARPA Management over a period of time. It is well understood that each technology transfer/insertion plan will be unique and must be tailored to the specific program. There are, however, substantial benefits to establishing a proposed plan at the outset of a program and encouraging the concomitant agreements with the target user Services, Agencies, and Industry. This is further discussed in section 3.4.2.2.

3.3.4 THE TECHNOLOGY TRANSFER PROCESS AT DARPA

3.3.4.1 GENERAL

Across the DARPA programs the techniques, methods, and procedures for accomplishing technology transfer appear to vary considerably, and are highly dependent upon the background and personal management styles of the management and Program Managers. Techniques currently employed include briefings which DARPA calls "DARPA Days", project-specific Future Application Committees, intense laboratory involvement, and direct transfer through follow-on prototype systems. It is conceded that in some cases the right technology will be rapidly exploited through its own "technology pull" mechanisms without any overt transfer program. However, DARPA is often in the position of promoting technology derived opportunities in their early stages, and is therefore required to take an early proactive role in pushing technology. The very nature of this necessary action, however, is often disconcerting to the System (Services, etc.). The System is fundamentally more comfortable with near-term planning and elements having natural technology pull. Thus, it is not surprising that DARPA is often accused by the Services of trying to push them into accepting poorly timed, ill fitting, or "out-of-doctrine" solutions to their problems.

For DARPA, the environment for technology transfer is multi-faceted. DARPA must be concerned with technology transfer for both the small high risk advanced technology thrusts and the medium to large scale technology demonstrations in bold areas of high potential. The Panel also recognizes DARPA's responsibility for technology transfer must address both specific applications (Blue Laser, BETA, etc.) and generic technology areas (Directed Energy Weapons, Strategic Computing Program, etc.). To aid in considering multidimensionality of DARPA's technology transfer the Panel chose to define two general categories of technology transfer at DARPA:

- Diffusion - The implicit transfer of technology throughout academia, industry, to other Service Labs, contractors, etc. and thus to eventual users. This process, although not always rapid, is usually multi-channeled and reliable. It often takes place with DARPA's 6.1 and 6.2 technology.

- Infusion - The direct transfer of technology via explicit technology demonstration aimed toward subsequent incorporation into a Service developmental system. It is this process which is typical of most large technology demonstrations.

Thus, within the DARPA environment, technology transfer addresses large and small programs, infusion and diffusion of technology, for both specific and generic technologies. Although we recognize the need for a properly balanced technology transfer program across this entire environment, this Panel, after much discussion and based on the largest area of concern, principally focussed on improvement of the technology transfer process associated with infusion for the Large Technology Demonstration Programs.

3.3.4.2 BARRIERS TO TECHNOLOGY TRANSFER

It will be useful at this point to identify some of the principal barriers to technology transfer applying to DARPA as perceived by this Panel and those interviewed as well as from prior studies:

- Basic Mission Differences:

  Difference between the mission and basic nature of DARPA versus those of the Military Services impede a smooth transition.

- Perceived Attitudes:

  It is sometimes perceived that DARPA usurps the Military's planned systems with top-down politics. Such a perception can in itself cause negativism.

- Recent Technology Trends:

  Trends related to overall technology proliferation and usage have tended to evolve in the following direction:

  - We are increasingly moving toward advantages stemming from integrated technologies, making technology demonstrations more complex and larger in scope. (BETA, Mini-Halo, X-29)

  - A concept demo may require, simultaneously, demonstration of related enabling technologies.

  - With today's highly integrated technologies and interoperability themes, multi-Service involvement may be required for payoff. It is difficult to obtain multi-Service cooperation for normal production programs, much less a high-risk advanced DARPA program.

  - A concept demo may include demonstrating competing technologies (ALV).

- Perceived Conflicts with Service/Agencies Laboratories:

  DARPA is generally earlier in the development cycle, but when committing to demonstrations they may be perceived as interfering with labs' charters.

- From 1981 DSB Summer Study (Ref. 2):

  A number of barriers were identified which generally inhibit the successful transition of technology into systems. There is little incentive to exploit or respond to new technology owing to:

  - Discontinuity of funding, indecisions, and the short-term orientation of many key decision makers

  - The organizational and spatial separation of technology base and systems people

- Very little emphasis on technology demonstrations which accurately portray risk reduction, payoff, and cost factors for later stage production

- Very little emphasis on "test marketing"

- A champion on the operational user side or user support is often not present

- From an internal DARPA presentation in 1984 (Ref. 1):

  DARPA, in a set of presentation charts which addressed the subject of technology transfer, identified the following as barriers:

  - Perception of competition with 6.4 developments

  - The "mysteriously disappearing" 6.3A budgets

  - High cost of next RDT&E phase

  - Competing approaches to similar problems

  - Lots of "blackball" potential (many can stop, only all can make go)

  - No Service "corporate commitment"

  - Competition with Service lab ideas

  - Revolutionary approaches don't fit the Services' system

  - Lack of POM wedge, POM planning

- Security Classification:

  "Black" programs should not be allowed to restrict use of technology unnecessarily. This potential barrier was not a focal point area of the Panel's study. It should be stated however, that during the course of interviews the subject of possible potential for over-classification was brought up several times.

3.3.4.3 CATALYSTS TO TECHNOLOGY TRANSFER

Just as there are many barriers to technology transfer, so also are there factors which in varying degrees can aid the technology transfer process. The Panel's recommendations, summarized in section 3.4, include changes aimed at maximizing use of these catalysts. Some important examples of such "catalysts" follow:

- Natural Technology Pull:

  Technology Requirement strong enough to create natural "Pull" into Services/demos.

  - Blue Laser (Real need to communicate, real solution)

- Stealth (Technology which makes an easily perceived predictable difference)

- I volvement of the User:

  Involve target Service(s) early, including early dollar commitment. Try not to bypass or be perceived as bypassing the Services. Relative to the fundamental problems of transfer of technology to operational use, there should be maximum communication to potential users. Future Applications Committees as currently being tried on the X-29 may be a partial solution. Early involvement of potential eventual users, along with specific tailored marketing plans could be a big help.

- Champion:

  Existence of a Service/Agency entrepreneur/champion will greatly assist technology transfer.

- Attitude:

  Share the credit and avoid the perception of directed use.

- Operational Involvement:

  Involve operational personnel early in the thinking. DARPA's sometimes reluctance to involve senior operational people on grounds they won't be around when the idea matures may be a serious mistake. These people may have much to offer regardless of their finite tenure, and they could help the tech transfer wheels turn more smoothly while they are still present and set the stage for understanding and acceptance when they hand over the helm to their successors.

- Transfer of Prototype:

  Transfer of prototypes to the Services/Agencies for field experiments is highly desirable. This can sometimes turn "technology push" into "requirements pull".

- Service/Agency Lab Involvement:

  Maximize two-way communications with labs and use of labs. Respect lab roles and expertise.

- Early Demo:

  Early demo of even partial feasibility helps to overcome the "I won't believe it until I see it work" syndrome.

- Realism and Planning:

  Some aspects of planning which are potential positives are:

  - DARPA must consider the implementation program. Eventual implementation must be perceived as feasible and useful.

- Special planning is required if the program goes against tactical doctrine (e.g. Assault Breaker) Can't change everything at once; can't force doctrine change; but might cause one, with proper and early communication and planning.

- A program either has to fit the existing way of doing business (infrastructure) or else must address changing it (e.g. BMD/SDI).

- Existing or proposed competitive programs must be addressed, both those competing for budget and alternative technologies.

- Miscellaneous:

  Some additional potential positive factors which warrant mention are:

  - The value of a sound program selection process cannot be overstated.

  - Exciting the industry participants and potential users is an important forcing function. Enthusiasm is contagious.

  - Excellence of briefers/briefings can be a significant factor.

3.3.4.4 CONSIDERATIONS RE PERCEPTIONS OF "SUCCESS" VS "FAILURE" OF DARPA'S TECHNOLOGY TRANSFER PROCESS

Within the context of technology transfer by "infusion", which is the principal focal area of this study, success is defined here as 1) the timely transition and exploitation of a technological opportunity (i.e. the right technology at the right time) or, alternatively, 2) the appropriate and timely decision to terminate or redirect the pursuit of that opportunity. Only a close working relationship between DARPA and the user can accommodate either without undue organizational discord.

During the Panel's study, it became abundantly clear that "success" or "failure" can often be strongly in the mind of the beholder. The dichotomy of opinion as to the relative degree of success of several of DARPA's past technology demonstrations is remarkable. Sometimes this was true to the degree of leading the Panel to wonder whether particular sets of people were in fact even talking about the same program. The existence of such diverse points of view is occasionally understandable based on different billets, backgrounds, or basic philosophies. Nevertheless, it is important to consider whether better communication of plans and purposes, especially at the outset of the programs, might have resulted in less dichotomy of opinion after-the-fact. Of far greater importance is the real possibility that the programs themselves might have been truly more valuable as seen from any viewpoint had there been better communication from their inception.

Notwithstanding the above hopeful possibility, it should be stated that DARPA and all potential users of DARPA's bold initiatives must maintain considerable perspective regarding the relative probabilities of simple, rapid and painless transfer of DARPA's advanced technology. Specifically,

the following points should be kept in mind by all concerned, even assuming future improvements to the technology transfer process:

- The road from initial gestation of technology to its operational use is often difficult and more lengthy than anticipated. This is especially true where the attempted initiative is in the nature of a "quantum leap".

- In the case of DARPA-originated technology the desired amount of "stretch" (the "10dB" initiatives) will often by their very nature involve high risk levels and some uncertainties of path, making even the planning process itself uncertain. The real final determinant of success vs failure is often staying-power to see the process through.

- The best well-chosen and well-conducted technology feasibility demonstrations will sometimes fail -- but, even in those cases, there often are valuable positive results in the form of spin-offs of technology very useful in other programs or in other contexts.

- Finally, there may be on rare occasions circumstances which warrant continued effort on DARPA programs even where technology transfer has not been successful. This is further discussed at the conclusion of the following section, 3.3.4.5.

3.3.4.5 LARGE TECHNOLOGY FEASIBILITY DEMONSTRATIONS

We now turn to the specific case of Large Technology Demonstrations which, as stated earlier, became the essential focal point of this study as it was perceived by virtually all to be the principal problem area.

Past and present management at DARPA have been keenly aware that technology transfer, in particular technology infusion in a timely effective manner, is a key responsibility of DARPA. The need to infuse the right technology at the right time (in time to make a difference) and the need to avoid technological surprises are principal goals well understood by all interviewed at DARPA.

Moreover, when discussing the technology transfer problem at DARPA and elsewhere, the Panel found almost universal agreement with those points related to the process itself, barriers and catalysts. However, the external world's view of DARPA's success in the area of technology transfer was often controversial (from all sides). Examples of this situation were cases in which DARPA felt that they had done everything humanly possible to obtain potential users involvement, only to experience severe downstream Service resistance wherein the potential users were extremely negative about the adequacy of DARPA's transfer efforts. The Panel therefore believes the difficulty is not in the philosophy, which all seem to agree on and believe in, but rather in the implementation of the technology transfer process.

As one positive step toward the improvement of this situation the Panel recommends the formation of an Advisory Board. This concept is discussed later in section 3.4.2.1 of this Report.

Recognized by many as a most important element, but also a large real problem regarding technology transfer, is the actual demonstration of the technology. In the mid-1970's DARPA chose to help solve this problem by sponsoring large feasibility demonstrations -- a step many agree is necessary as opposed to merely pure analysis or component level proof-of-concept experiments. The technology feasibility demonstration, as discussed here, is the principal means for the specific infusion process of technology transfer as distinguished from the diffusion process by which much general technology is transferred (see Section 3.3.4.1). The primary purpose of Large Technology Demonstrations is to assist transfer through determination of military worth. Unfortunately, in some cases this has been inferred to mean "Ready for Full Scale Engineering Development". This is often disputed by the Services/Agencies who believe they must characterize the technologies further prior to FSED. The determination, degree, and the manner of coordinating such technology feasibility demonstrations are important issues to be considered. This is discussed further in section 3.5. The Panel feels DARPA should take additional steps to maximize the probability of acceptance and further development by the appropriate Service/Agency when and if the demonstration is successful technically.

In terms of program execution, there were originally two fundamentally different approaches to the time-phasing of DARPA support and control and hand-off to the Services/Agencies. The first, which was the "traditional" DARPA mode, is that of focusing on the technology. In this approach, DARPA supports the technology development only to a point at which most critical issues have been resolved and the solution to the military problem appears possible. At this still early point DARPA funding is discontinued and the technology will presumably be applied to a military problem by industry. This approach has the inherent danger that a given technology will be delayed in being utilized or, indeed, may never be used. It is, however, a satisfactory approach at times, especially in cases of technology transfer by diffusion.

The X-29 Technology Test Bed is an example of the second approach which is closely related to the question of Large Technology Demonstrations, and is based on the perception that the best way to transition technologies is to get prototypes on into the field where they can sell themselves. This concept assumes continued DARPA support and control through the complete development and demonstration of the concept. It was this philosophy which led to the inception of Large Technology Demonstrations in the late 1970's. This approach has difficulties as well since programs using this approach are much more expensive for DARPA, and there is no certainty of Service/Agency commitment or acceptance even with a successful demonstration.

In some cases such demonstrations, fully funded and mostly managed by DARPA, have failed to generate significant Service/Agency support because, for example, they have been looked upon as "OSD hobby shops" which have little real world value. Also, there is absence of early Service/Agency support to budget for follow-on exploitation of the demonstrations (i.e., the prototype phase). True Service involvement, including real utility assessment and serious consideration of follow-ons, occurs best when the Service has significant commitment to the demo such that senior headquarters/secretariat staff must keep abreast of the effort and provide its support.

The Panel has examined programs executed at DARPA with both the first and second approaches described above. Varying degrees of success were achieved. Still other programs which were perceived as successful in some degree, however, were found to have employed a third, or hybrid, approach which DARPA has more recently been using. Typically, such a DARPA new-start has Service/Agency connection from the beginning of the technology feasibility phase. Although DARPA funds most or all of the technology phase, Service/Agency commitment is established by means of an Agreement reached among the parties prior to program start and, in some cases, some funding contribution. The Agreement must provide for increasing Service/Agency share of funding as the program passes through the Concept Demonstration phase as well as the plans for transition of management from DARPA to the Service/Agency. Also often included in the Agreement is a commitment for a wedge in the Service/Agency POM for subsequent prototype development. (Such a wedge does not constitute a guarantee to actually develop the prototype, however.)

This newer, hybrid, approach appears to have the potential for improving DARPA's coupling to users and, thereby, improving chances of ultimately transitioning technology to the Services/Agencies. There are difficulties in implementing this approach also however. The challenges in negotiating the agreement and in the subsequent management of the programs are considerable. In some ways such programs are similar to large joint Service programs, which are often prone to problems. This issue of Service Management of Large Technology Feasibility Demonstrations is further discussed in section 3.4.2.1.

It must be noted here that on rare occasions special circumstances may dictate the continuance of a DARPA initiative even where successful technology transfer does not occur in spite of the best efforts of all concerned. Such a case might occur, for instance, where the Congress and/or OSD feels that a continuation of effort is critically necessary to ensure that the nation has an alternative capability as a hedge in the event of major hostilities. Another circumstance warranting a request for continuance might be where an as-yet untransferred program clearly offers a tactical or economic advantage of such compelling potential magnitude as to warrant further prove-out and demonstrations. In these unusual situations, DARPA, by virtue of its unique charter is virtually the only organization which can provide this service to the nation. A recent example of an effort in this category is the field of directed high energy weapons.

3.4 CONCLUSIONS AND RECOMMENDATIONS

3.4.1 CONCLUSIONS

In consideration of all of the foregoing factors bearing on DARPA's technology transfer process, the Panel feels that improvement can be achieved if certain steps are taken by DARPA.

Technology opportunities identified at DARPA and pursued through Large Technology Demonstrations may be viewed as programs having life cycle phases of selection, planning, development (tech demo), evaluation and transition. Having reviewed the various criticisms of the process, its attributes, barriers, and catalysts, the Panel has concluded that a principal driver of a successful transition is a close supplier/user relationship (DARPA/Service)

that is promoted and encouraged throughout the life cycle of a given technology opportunity, namely, from selection through transition.

Accordingly, the Panel offers the following recommendations:

- DARPA should continue Large Technology Demonstrations of a 6.3A nature in addition to continuance of its traditional 6.1 and 6.2 technology activities.
- No new Agency should be established for the purpose of conducting Large Technology Demonstrations.
- DARPA should establish an Advisory Board to improve up-front two way communications with the potential users of DARPA's technology.
- DARPA should continue to press toward an increasing role for the Services in management of the Large Technology Demonstrations.
- DARPA should be prepared to fence the necessary 6.3A funds to ensure accomplishment of these demonstrations.

The Panel feels strongly, based on its study, that these recommendations, if followed, will result in real and substantial improvement to DARPA's technology transfer process in the area of Large Technology Demonstrations. This will be achieved through better and more participatory planning and an improved partnership with the user Services/Agencies. We further believe these improvements can be implemented without undermining the very necessary and desirable freedom of DARPA to act boldly with the advanced technology thrusts which are of high importance to the Nation's defense posture.

These recommendations, and several others related to them, are more fully discussed in the following section of this Report.

3.4.2 RECOMMENDATIONS

Most elements of the Panel's recommendations have been alluded to or discussed in varying degree within the appropriate prior sections as they occurred in order to provide continuity for the reader. Acknowledging some repetition, this section brings together all of those recommendations to provide an overall perspective and to focus and convey the Panel's regard for relative priorities.

Certain of the recommendations are considered to be of highest priority. Others are related to and also supportive of the objective. Accordingly, the recommendations are priority-grouped as follows:

Primary Recommendations

- Advisory Board
- Service Management
- New Agency Issue

Related Recommendations

- General
- Personnel and Organization
- Selection of Programs
- Technology Transfer Initiative

3.4.2.1 PRIMARY RECOMMENDATIONS

- ADVISORY BOARD

An Advisory Board should be formed to review the proposed large technology demonstrations before-the-fact. This Board should be composed of both OSD and senior operational Service people. It should not be given the power to commit or veto DARPA programs. The principal purpose of this Advisory Board will be to ensure that during the initiation phase of Large Technology Demonstrations there is an early and open two-way forum for communication of plans, potential user comment, and preparatory actions for participation throughout the life cycle. The essential functions of this Board would be as follows:

- Learn about DARPA-proposed concept demonstrations early-on.
- Offer user's perspective to DARPA's concept demos early-on.
- Where appropriate, suggest synergistic possibilities with Service/Agency lab technology.
- Advise/suggest as to an optimum process for technology transfer of specific programs into the system.
- Where appropriate, assist in planning for and expediting technology transfer of particular proposed concepts through Large Technology Demonstrations.
- Make suggestions/recommendations to DARPA as to who should manage particular Large Technology Demonstrations.
- Offer DARPA thoughts as to other candidate areas needing future breakthroughs (iterative exchange of ideas).
- Give potential users advanced awareness as to possible future availability of technology from DARPA.

The Advisory Board should meet as often as necessary and at those times most appropriate as to ensure optimum performance of its functions.

The Panel has considered a related question: Which of DARPA's many programs should utilize this Advisory Board? Clearly, early small technology efforts, especially of the diffusion type, do not strictly require it although it may be valuable for DARPA to communicate some of the more important of these to the Advisory

Board to establish advanced awareness. Even certain highly-urgent quick reaction (and perhaps highly classified) programs might not need full Board involvement in cases where they are of such strong and urgent identifiable need as to ensure rapid and certain technology transfer.

The principal need for an Advisory Board function lies in cases of proposed Large Technology Demonstrations especially of a specific systems nature, representing potential rapid infusion of advanced technology into the system. As to a definition of what constitutes a "Large" investment of this type versus a minor investment, the Defense Science Board has recommended a $30 million threshold. Others have broadly suggested "100's of millions versus 10's of millions" as the break-area. The Panel generally concurs with these approximate magnitudes of differentiation but further suggests that other parameters and circumstances should be considered in each case. These are:

- The importance and urgency to the nation of a particular program as expressed by the magnitude of the potential breakthrough and its need for rapid timing.

- The relative simplicity of a single potential user versus the complexity of multiple potential user organizations.

- The perceived simplicity versus complexity of eventual implementation (doctrine-change implications probably representing a worse case).

- The importance of early discussions with potential users relative to very advanced key technology (even in cases where the DARPA program may still be a small one).

- SERVICE MANAGEMENT

Service Management of Large Technology Demonstrations is highly desirable to assist technology transfer. Although progress seems to have been made in this area, in DARPA's present operating mode sometimes the Service management role is one of administration, financial programmatics, and only minimal technical participation. While better than no involvement at all, this is not as effective as where technical management is assumed by the Service. Higher-echelon Service involvement and support are very desirable also (as seems to have been achieved in some Navy-oriented programs).

DARPA should therefore continue its important efforts toward achieving a situation whereby the user Service/Agency will truly manage large demo programs. In the ideal case, the Service/Agency would provide day-to-day technical direction in addition to procurement and administrative functions, while the DARPA technologists would serve as technical advisors, with significant technical authority vested in DARPA.

However, notwithstanding Service Management, DARPA must in many cases continue to fence the majority of the necessary 6.3A funds, as they are often better able to do so than the Services.

Such Service Management involvement offers the following advantages:

- By becoming an early participant, the user undertakes a corporate commitment.

- It promotes an early participative dialog on the selection and optimization of the technology transfer initiative for a given technology.

- It encourages early up-front "what if" communications with operating people on important technology feasibility demonstrations. This process may occasionally alter and improve the direction of those technology demonstrations.

- It permits Services to initiate preliminary plans to pick up subsequent phases of the feasibility demo if the initial phase proves promising, including any possible need for future doctrine changes.

In summary, the Panel believes the technology transfer value of having technical and potential operational user involvement in the selection, planning, requirements definition, development and evaluation of a technical opportunity cannot be stressed too highly.

- NEW AGENCY ISSUE

A prior recommendation of others was the creation of an independent Advanced Projects Agency to take DARPA technology into demonstrations. The Panel believes that such a step would add another layer of bureaucracy, reduce DARPA flexibility by requiring the "New Agency" acceptance of the program, and would only move the transition problem from a DARPA/Service interface to "New Agency"/Service interface. The Panel thus recommends direct DARPA/Service interface and technology transfer with maximum Service Management as outlined above rather than creation of a permanent new Agency.

3.4.2.2 RELATED RECOMMENDATIONS

- GENERAL

  - DARPA's Role

    DARPA's focus should remain on the longer term, high-potential payoff (and often high risk) programs not generally undertaken by Services or other Agencies. DARPA's role should continue to include the traditional smaller technology investigations (6.1 and 6.2 funding) as well as concept demonstrations (6.3A), but with the larger of these truly Service-Managed wherever possible.

- Technology Demonstrations

  DARPA should continue Large Technology Demonstrations to prove feasibility, facilitate transfer, and to enable evaluation of military worth. In many cases this is the only way to ensure timely insertion of bold advanced technology into the system.

- Funding

  From the standpoint of encouraging and optimizing technology transfer, it would be desirable to have the potential user provide significant funding support during these technology demonstrations. However, since the Service may not always be able to effectively fence sufficient funds, DARPA must often accept the responsibility for fencing the majority of tech demo funds even in cases of Service Management of the tech demos.

- PERSONNEL AND ORGANIZATION

  Based on the issues as discussed in section 3.3.3.3, the salient recommendations of the Panel in this area are as follows:

  - DARPA should continue use of its current criteria for seeking and hiring new people.

  - Major growth of DARPA staff in large-program management should be avoided. Rather, effort should be continued toward maximizing use of Service personnel on the large programs.

  - The present situation wherein a single Program Manager monitors up to 15 or more contracts is undesirable for adequate cognizance and management and should be alleviated through some combination of reduction of programs/contracts, combining of programs/contracts where applicable, greater use of Service/Agency personnel and perhaps some slight increase in staff where appropriate.

- SELECTION OF PROGRAMS

  Based on the issues as discussed in section 3.3.3.2, the Panel's recommendations in this area are as follows:

  - DARPA's selection process should include, for background purposes, greater use of Service inputs, ROC's, SON's, relevant DSB studies, etc.

  - For general perspectives, DARPA should consistently use, at least informally, a "catechism" similar to that outlined in the DSB 1981 Summer Study (Ref. 2) as a useful test/discipline at the outset of a program.

  - An additional question which should be raised at the time a program is selected is what other (ancillary) developments may be required, and on what time scale, to enable the primary program to be implemented (potential related technology transfer barriers).

- TECHNOLOGY TRANSFER INITIATIVE

  Technology transfer strategies should be a major concern of the Director, Deputy Directors, and all Program Managers at DARPA. A Technology Transfer Program should in itself be a required initiative for DARPA especially on all Large Technology Demonstrations. To this end, the Panel recommends:

  - DARPA should establish and make available to all Program Managers a central historical data base or "corporate memory" of successful technology transfer strategies based on actual program experience. This resource, which should also record unsuccessful experience, should be utilized by Program Managers when planning and embarking on a new program, as a guideline to assist in developing an appropriate technology transfer plan.

  - A new office within DARPA might be established to generate and maintain this experience data bank/strategy guideline. This is not recommended, however, if the task can be accomplished within DARPA's current organizational framework.

  - DARPA technology transfer strategies should span all aspects of the technology opportunity life cycle from selection through transition and/or insertion. This is a very difficult process, but the results should be well worth the effort in promoting smooth and rapid technology transfer.

  - Additionally, early participation by the effected defense Agencies or Services using a life cycle perspective would give the potential user a leg up in the necessary modification and replanning of 1) budgets, 2) alternative or competing technologies, and/or 3) doctrine, to allow for an effective and expedient transfer.

  - The concept of developing technology transfer plans might well be useful in the more generic technology areas within DARPA as well, and indeed might even be developed with industry dialog and support. Such a process may be desirable as a mechanism to increase industry cooperation and so hasten even cases of "technology diffusion".

3.5 SOME ADVANTAGES AND CONCERNS RE THE PANEL'S RECOMMENDATIONS

On reflection, the Panel feels that a few words are appropriate on the advantages and also on some concerns relative to its recommendations.

Some advantages to the Panel's recommendations toward improvement of DARPA's technology transfer process can be summarized as follows:

- They utilize the existing organizational structure

- They facilitate technology transfer through "corporate commitment" and familiarity

- Funding is protected to ensure completion of feasibility demonstration

- Mechanism is provided for early dialog on such issues as soundness of technology; who should manage the demos; and the possibility that slight changes to the program could be leveraged to make large differences in its transferability.

- They help ensure that demos focus on military needs/applicability

- They offer potential users insight and guidance as to other available DARPA advanced technology

- They help the promotion of synergistic ties to Service/Agency lab activities

- They will promote an environment which generally utilizes the catalysts, softens the barriers, and encourages early and continuous user involvement.

Notwithstanding these benefits, the Panel recognizes that there may be certain concerns with its recommendations. Some of these possible concerns are outlined below:

- We strongly emphasize the Advisory Board is advisory only. The ultimate decision to proceed or not should be DARPA's alone even in the instance of dissent on the part of the Advisory Board. Given the high caliber of people assigned to the Advisory Board, one should not anticipate a problem with understanding their role as advisors and communicators as opposed to exercising control.

- The Services may still need to do their own pre-FSED demonstrations. If they have managed the technology feasibility demonstration, they may be criticized for poor planning in not combining the two. A solution to this concern would be to develop a plan at the outset that either acknowledges the two different types of demonstrations or else purposely combines the two. This plan, if agreed to by the Advisory Board, the user, and DARPA, would provide the necessary backup to offset later hindsightedness.

- The funding of overruns or out-of-scope changes that frequently take place in technology demonstrations will be more difficult where funding is provided by DARPA but where considerable technical direction is provided by the user community. Once DARPA has a commitment and the program is underway, it will be difficult not to fund overruns. Such overruns may be caused, at least partly, by the managing Service/Agency. It is the Panel's belief however, that this issue is not unlike other management issues and can be reasonably handled if a part of the agreement at the outset of a program addresses this issue and the funding organization is given final authority before any changes occur.

- A related problem, which some perceive to be a serious one at DARPA, is that the 6.3A program overruns are sometimes covered by shifting funds from DARPA's 6.1 and 6.2 programs, to the detriment of longer

range technology and planting of seeds for the future. This perceived problem, which was not within the scope of the Panel's Study, could be exacerbated by any increased 6.3A funding role by DARPA. It is a problem which needs to be addressed in its own right, however, regardless of action on the Panel's recommendations.

- Another area of possible concern related to the possibility that establishment of the Advisory Board may tend to drive DARPA's Large Technology Demonstrations toward shorter term objectives and less "bold leaps". It is the Panel's feeling that, as stated earlier, the high caliber and maturity of the Advisory Board members will not allow this to happen and that on balance the Large Technology Demonstrations can still be "bold" but will undergo more effective and rapid transfer to the user community as a result of the Advisory Board's existence.

4.0 REFERENCES

1. DARPA Internal Presentation, dated February 13, 1984.

2. Report of the Defense Science Board 1981 Summer Study Panel on Technology Base (U), November 1981, USDRE, Washington, DC 20301, ADC027500, Secret.

3. Report of the Defense Science Board 1982 Summer Study Panel on New Weapons Concepts (U), November 1982, USDRE, Washington, DC 20301, ADC030727, Secret.

4. Millburn Committee on Critical Technology Demonstration Draft Plans and Responses, May to July, 1983, committee established USDRE 4 March 1983.

5. USDRE Independent Review of DoD Laboratories, 22 March 1982, Prepared by Dr. Robert J. Hermann, ADA118006.