Transitioning DARPA Technology

Potomac Institute for Policy Studies

TRANSITIONING DARPA TECHNOLOGY

FINAL TECHNICAL REPORT

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14. ABSTRACT
The goal of this study was to address how and how well DARPA has transitioned products to the Military Services. The report also addresses how that mission has been affected by the nature of the Agency and its output, and by the environment in which it operates. The report tracks program and product characteristics for the last decade (1990s) and new starts begun at DARPA during FY 1991. The study documents three canonical transition paths and five strategies commonly used by DARPA. It offers recommendations from conclusions suggesting ways to improve transition performance.

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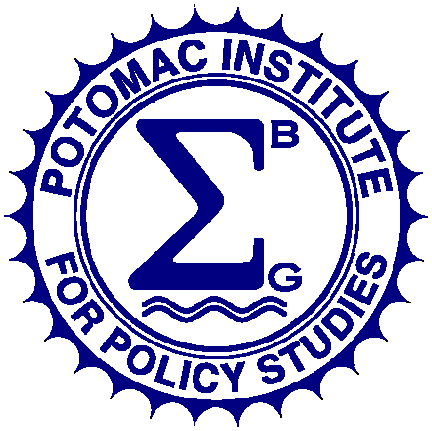

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The conclusions of this study are our own and do not necessarily represent the views of the sponsors or participants.

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Preface

The study was performed under a DARPA contract. Mr. John Jennings, the DARPA program manager, contributed both information and ideas. In conducting case studies and preparing this report, the Institute also interviewed many people from within the Agency, industry, academia, and other government organizations. We cannot mention all of them here, but we would especially like to express our appreciation to: Trent Depersia; CAPT Dennis McBride, USN (Ret.); Rick Dunn; Dr. Mel Ciment; Pete Worch; Jeff Bullington; Bill Marks; Dr. Steve Wax; John Jennings; Sven Roosild; Dr. Robert Leheny; Dr. David Honey; Dr. Andrew Yang; Dr. Drew Glista; Dr. Raymond Balcerak; Dr. David Patterson; Dr. Hilarie Orman; Dr. John Toole; Dr. Hank Dardy; Dr. Paul Mockapetris; Dr. Robert Tulis; Dr. Darrel Hopper; Chris Spiegel; Dr. Mark Slusarczuk; Dr. Richard Koyama; J. William Doane; Gene Miceli; Michael Ciensinski; Dr. Frank Patten; Dr. William Barker; Dr. James Butler; Dr. Ben Wilcox ; Dr. Larry Fahrenbacher; Dr. Brian Boesch; Dr. Michael W. Masters; Riva Meade; Major Doug Deyer, USAF; Frank Schrenk; Dr. LN Durvasula; Dr. Bert Hui; Dr. Robert Rosenfeld; Dr. Ronald Kostoff; and Pat Sullivan. However, the contents of this report are the responsibility of the Institute and are not necessarily agreeable to other contributors.

A major part of this study was dedicated to finding ways to characterize the transition record of an organization like DARPA, one that spends much of its capital on high risk/high payoff and innovative technical solutions to large problems. Although volumes have been written about product insertion, one quickly finds the specifics of the products and circumstances under which they are developed and marketed dominate the way an organization transitions its wares and the degree of success it has in doing so. In this work we attempted to characterize those specifics. In some instances, this necessitated choosing and assigning values to descriptors of the products and the programs that led to them. We would have enjoyed soliciting more opinions on this process, particularly on the values assigned, but as in life itself, there was no time. We would be grateful for any comments on this or any other aspect of the report. Please send comments to tennyson@potomacinstitute.org.

Executive Summary

"I want an agency that makes sure no important thing remains undone because it does not fit somebody's mission." Neil McElroy, Secretary of Defense, 1957

A. Background

The Defense Advanced Projects Agency (DARPA)[1] was formed in 1958 to address our nation's move into space. Since then the Agency has received many assignments, although its overall mission and character have remained fairly consistent. During this time, immensely diverse products have emerged to find their way into our nation's space, defense, academic, and private sectors. In this project, the Potomac Institute for Policy Studies (the Institute) was asked to develop and document an understanding of how well DARPA has transitioned these products into military systems over the past forty years. The above quote is a reminder that, as important as transition is, it is not the only responsibility delegated to the Agency. This and other factors affecting DARPA's transition rate were considered.

Earlier studies have substantiated the impressive array of products DARPA has developed and transitioned into various military systems. The Agency has provided basic work in science and technology that has enriched the programs of military laboratories and the defense industry alike. Significant "spin-offs" (from the defense sector to commercial industry) and "spin-ons" (from commercial industry to the defense sector) have also resulted from DARPA programs. Perhaps as noteworthy are the commercial and government organizations created to improve, manage, and apply DARPA-supported technologies, some of which have continued to set industry-wide protocols, perform precompetitive research, and insert technology and products into military systems.

DARPA has conducted programs at nearly all stages of acquisition, certainly spanning research (6.1) to application (6.3), to address customers across the spectrum of the Military Services, from researcher to user. Historically, a unique feature of DARPA is the breadth of its programs and its military customer base. Unlike most Service acquisition organizations, which most often address one or two groups of users, DARPA's approach has been to seek a broad range of customers. This flexibility also brings some complexities into the lives of Agency program managers. They must be familiar with a wide span of work in their field, application of their technology, and environment under which the technology is to be used.

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[1] DARPA, then called the Advanced Research Projects Agency (ARPA), was established by Department of Defense Directive Number 5105.15 on February 7, 1958. Public Law 85-325, dated 12 February 1958, called upon the Agency, "…to engage in advanced projects essential to the Defense Department's responsibilities in the field of basic and applied research and development which pertain to weapon systems and military requirements as the Secretary of Defense may determine after consideration with the Joint Chiefs of Staff…" Although the name of the Agency has changed back and forth from ARPA to DARPA, we will refer to it by its present name, "DARPA" throughout this report. Likewise, we have referred to organizations and positions by the names and titles they bear today.

B. Goals of the Project

This report is essentially a study of how and how well DARPA has transitioned products to the Military Services. The report also addresses how that mission has been affected by the nature of the Agency and its output, and by the environment in which it operates. The study had four goals:

1. To examine DARPA's history of transition to its military customer;
2. To empirically identify transition paths and strategies employed by DARPA;
3. To identify factors that affect DARPA's transition rates and to cite recent changes in those factors; and
4. To suggest how DARPA might improve transition.

C. Study Approach and Organization of This Report

In this Executive Summary, we offer a brief statement of our approach to the project. We also present several conclusions and recommendations developed and discussed throughout the five chapters. In order to accomplish the four study goals, we drew from the wisdom of past studies but we also collected additional data and developed new approaches to process and apply them.

Chapter I addresses how the Institute developed a taxonomy for understanding and assessing DARPA's transition record, and presents data on product and program characteristics pertinent to transition. We compiled a list of 124 past DARPA programs (see Table A-1 in Appendix A), but concentrated on two subsets of this program population.[2] Programs transitioned during the last decade (1990s) were chosen because it would be easier to obtain information on them than on earlier decades. Program and product characteristics for this period are listed in Table A-2. The second program population, a subset of the last decade, is the New Starts (or initiatives) begun during Fiscal Year (FY) 1991. We tracked each of these new starts until they transitioned products, failed and were abandoned, or continued development with possible transition pending.

Chapter II presents three canonical transition paths and five transition strategies commonly used by DARPA. We illustrated these paths and strategies with numerous examples drawn from past DARPA program and product transitions.

In Chapter III, we discuss other DARPA missions, organizational policies, and external factors that affect transition, either impeding or improving its prospects.

The 1991 "New Starts" study results are reported in Chapter IV, with a summary table on the program and product characteristics in Appendix A-3. The New Start case studies, featuring interviews with participants in DARPA's programs, are reported in Appendix B. These eighteen

[2] We also incorporated insights gained from the Institute's study of DARPA's Technology Reinvestment Project (TRP), reported in [19].

New Starts represent a cross section of DARPA's programs and were objectively selected with no bias toward either success or failure.

Finally, in Chapter V, we offer seven recommendations from conclusions developed earlier, suggesting ways to improve transition performance.

Definitions of terms and acronyms used throughout this report are listed in Appendix C and references to pertinent publications are found in Appendix D. Through out this report, numbers in square brackets correspond to the numbered references in Appendix D.

D. Conclusions and Recommendations

This section highlights the principal conclusions and recommendations of the study—an integration of selected data, analysis, and ideas developed in the report. They are clarified and sometimes quantified over the next five chapters. **(**Major conclusions appear in bold italics.)

Goal #1. Document and assess DARPA's transition history. To address this goal, we examined the Agency's success in getting its products into the Military Services it supports.

First, we defined several program and product characteristics needed to understand this and subsequent goals of the study. We refer to DARPA's output and the system or component that is finally fielded as the "DARPA Product" and the "Final Product," respectively, in order to distinguish between the products at these two stages. The event that transforms the DARPA Product into the Final Product is the "Transition" and the path it follows, the "Transition Path." We identified the scale of the program under which each DARPA Product was developed as large (greater than $100 million) or small (less than $100 million). In order to describe the maturity level of the product as it leaves DARPA, we adopted NASA's Technology Readiness Levels (TRL) [30] as explained in Chapter I.

The Institute then rated the impact (or usefulness) of the Final Product as Significant, Very Significant, or Disruptive. The disposition of the Final Product was also noted either as a "system" or a "subsystem, component, or technology" in a fielded or major developmental system.

Three canonical transition paths from DARPA to fielded (or sometimes major developmental) systems were identified. A major distinction among these paths concerns the identity of the organization that sponsors the technology after it leaves DARPA. The DARPA-to-Service Acquisition (DSA) path moves products from DARPA to the Service acquisition system to be directly incorporated into a fielded system.[3] *Here the participating industry often does the marketing to the Service, but does so as a contractor to DARPA, and furnishes little or no funding. Funding responsibility for insertion is passed to a Service acquisition organization.* The DARPA-to-Industry-to-Service Acquisition (DIS) path moves products from DARPA to industry, which then transitions the product to the Services. *In this case, industry spends significantly of its own funds in developing or applying the product, and then transitions it to the*

[3] Throughout the study, we also gave credit to transition for those DARPA Products adopted into major developmental programs, since this seemed auspicious to fielding.

Service acquisition organization, which funds the fielding and any necessary modifications needed to make the product work in a military role. The third path is DARPA-to-Service science and technology (S&T) organizations (DS&T). *In this approach, a technology moves from DARPA to a Service S&T organization, which develops the technology further (using S&T funding) and inserts it into a fielded or major developmental program through its acquisition system.*

Assessing transition performance for a research and development (R&D) organization, particularly one with DARPA's mission and operational strategies, is an inexact and argumentative undertaking—not given to a "single number" answer. After much thought, data collection, and analysis, we came to believe that DARPA's transition record should be viewed from many perspectives and that the best way to judge its accomplishments is through a composite of these views. We chose the four perspectives listed below that together describe DARPA's transition performance and affect the standards of success under which it should be judged. But, for the most part, that judgment remains somewhat subjective, principally because of the difficulties in arriving at an objective standard for success.

1. **Total number of products transferred to the Military Services by DARPA.** We tabulated transitions for three periods of DARPA's history (the entire forty year life span of the Agency, the 1990s Decade, and the FY 1991 New Starts). This provides an appreciation for the sheer volume of DARPA's contribution.
2. **Rate of transition, in terms of transitions per number of programs initiated.** Because of limited data, we could only provide this measure for two program populations, DARPA's Technology Reinvestment Project (TRP) and the FY 1991 New Start Initiatives. Industry has developed standards of success for this approach and we applied these to DARPA.
3. **Quality of products.** We chose three indicators of the quality of DARPA's transitioned products: maturity of DARPA's output, final product disposition and impact.
4. **Other factors that affect transition.** We must also acknowledge other Agency responsibilities that vie with transition for emphasis and resources. We did not attempt to set their priorities. For instance, we acknowledge that DARPA's mandate to take on high risk/high payoff goals must be balanced against the Agency's transition rates, but we did not suggest what that balance should be. Circumstances, both external and internal to the Agency, also impede or improve transition opportunities and affect performance expectations. So, these factors primarily affect the standard for success adopted.

These perspectives are established and reflected throughout this report. We believe that the major conclusions presented are well supported by facts and logic and, if adopted, the ensuing recommendations would improve an already impressive record of contribution by the Agency.

Conclusion 1. Analysis of DARPA's record from the four perspectives (number of products transferred, rate of transition, quality of products, and missions and circumstances), led us to the conclusion that the Agency's transition performance has been impressive. Moreover, there is ample evidence of many uncounted successful transitions, particularly during DARPA's early history.

Goal #2. Define frequently used transition paths. To address this goal, we investigated the three canonical transition paths: DARPA-to-Service Acquisition (DSA), DARPA-to-Industry-to Service acquisition (DIS), and DARPA-to-Service Science and Technology (DS&T). We also offered examples of products that have transitioned by each path. Conclusions listed below are clearly and consistently borne out by the data from both the 1990s Decade and the FY 1991 New Starts, and are further discussed in Chapter II.

Conclusion 2. Each of the three canonical transition paths examined for the 1990s Decade products had some unique features:

a. ***About 60 percent of DARPA's products followed the DSA path.*** The most commonly used path, DSA depends upon DARPA's ability to attract the Service acquisition community or the users they serve. This path has been especially effective for "customer pull" strategies.

b. ***Products moved along the DIS path 30 percent of the time.*** This path was particularly successful for small programs. On average, the impact of these products was rated highest. All of these programs attracted industry cost share, which may explain the relatively low percentage of large (high cost) programs under this transition category. Products on this transition path were more mature when they left DARPA—probably due to the contributing industry's interest in getting the product to market quickly. One would favor a DIS path if the product had potential for dual use.

c. ***The DS&T path was used 10 percent of the time.*** The availability of a Service Laboratory partner, especially one with influence on the Service customer, or the development of an immature military technology that DARPA wishes to move out of the Agency for further development and application, may lead to consideration of the DS&T path. This assumes that the Service S&T Laboratory has sufficient knowledge to complete the development of the technology in question. On average, products that followed this path had less impact than those taking either of the other two.

Goal #3. Identify factors that affect DARPA's transition rate. To address this goal, we analyzed the factors that either impede or improve transition potential at DARPA. Some of these factors stem from DARPA's mission or organizational characteristics and policies. Others are part of the environment under which the Agency must transition its products. We also looked at changes in these factors that have occurred as the result of new trends in our world during the past ten years—changes in political, military, business, and R&D environments that have, or should have, affected transition.[4] Our conclusions are listed below, and are further discussed in Chapter III.

[4] Except for the data from the 1991 New Start Studies, we do not claim a statistically valid database to examine why transitions failed. Although we have documented over 120 successful transitions, and can usually identify contributors to success, we did not attempt to document all of the failed transitions, so we cannot claim to understand the absolute influence of that factor on success or failure. However, where we have found evidence of a positive or negative influence by these factors, we have reported it and have tried to give it proper weight.

Conclusion 3 (Organizational Characteristics).

a. ***DARPA's mission elements.***

- **i.** ***Solving national-level problems is an important DARPA mission, but the resulting products and technologies are generally more difficult to develop and transition than solutions provided for lower-level, single-customers.***
- **ii.** ***DARPA's mission also emphasizes pursuing radical innovation with high risk/high pay-off programs. This also often results in products that are difficult to deliver and to transition.***

b. ***DARPA's operational characteristics and policies.***

- **i.** ***High program manager turnover makes transition more difficult. Combined with difficulties in record keeping, this factor has also resulted in a loss of credit for many transitions that received significant DARPA sponsorship.***
- **ii.** ***Most of the Agency's successful research and development is accomplished and transitioned by industry, acting either as contractors to the Agency or independently as private sector entities. In either case, the industry partner often neglects to give DARPA's sponsorship the credit it deserves.***
- **iii.** ***DARPA/industry/academia consortia have had major impacts on commercial and military markets.***
- **iv.** ***The Agency's flexible management and contracting procedures have been a major benefit in dealing with industry and, ultimately, in transitioning to commercial and military markets.***

Conclusion 4 (Environmental Factors). The environment in which DARPA must operate also affect transition.

a. ***Military Customer: DARPA's military customer is often extremely risk averse and channeled to conform to a specific schedule of technical and program events. DARPA's transitions will be affected by the weakening of the federal laboratories. New avenues for transition, initiated by Office of the Secretary of Defense (OSD) and the Services can be of great benefit as well.***

b. ***Timing: There are numerous twists of fate that bend the path to transition. Difficult to predict, these factors must often be "waited out." But DARPA has few effective mechanisms for continuing to "market" its products after the program is over—particularly when the program manager has departed the Agency.***

c. ***Regulations: The Planning, Programming and Budgeting System (PPBS) and other manifestations of the Department of Defense's (DoD) bureaucratic processes provide their share of pitfalls along the path as well.***

d. ***Budgetary Considerations: It is to be supposed that reduced procurement budgets in DoD have diminished the market for new technologies, adversely affecting technology transition.***

Conclusion 5. Transition at DARPA is an opportunistic pursuit, greatly enhanced by skilled and dedicated DARPA and industry program manager and Service agent teams. It is likely that any structure or procedure that limits the program manager's sense of responsibility or options to transition his or her products will negatively affect the Agency's rate of transition.

Goal #4. Suggesting what DARPA should change. Chapter V offers some suggestions on implementing changes to DARPA's transition strategies and policies. We discussed each recommendation in light of our findings and analyses and other studies. Listed below are what we believe to be the five most compelling actions for DARPA to take.

Recommendation 1. Maximize the effectiveness of the DARPA and industry program manager and Service agent team. Transition success was highly dependent on the individual DARPA program managers, industry program managers, and Service contracting agents acting as a product champion team. In view of the importance of this team, it would seem logical for DARPA to concentrate on making it more effective. The strategy we recommend has four thrusts: 1) matching new program manager's tenure at DARPA to the expected length of the projects they will run; 2) helping new program managers become effective as quickly as possible through training and mentoring programs; 3) making program transfers from departing to incoming program managers as efficient as possible, and motivating new employees to treat inherited programs as their own; and 4) establishing incentives for product champion team members to transition their products.

Recommendation 2. Exploit recent avenues of transition initiated by OSD and the Military Services. By equipping the program managers to take advantage of special OSD- and Service-initiated mechanisms for transition, DARPA would make the most of the two major components of product insertion, product champions, and avenues suitable for the products to be transitioned.

Recommendation 3. Develop a better system of tracking and recording transitions and lessons learned and integrating the results. Essentially all world-class individuals and organizations assess their performance. Likewise, DARPA must constantly evaluate how well it accomplishes assigned missions. In the case of transition, the Agency should institute a better system for tracking and rating individual product insertions, and learning from their experience.

Recommendation 4. Address problems associated with "market timing." Related to the above, luck and timing often combine to define transition potential. Transition can go wrong (or right) through no fault of the program manager or the product. When this happens, and if the product in question has good potential, DARPA should sometimes stay in the game and continue to try to transition it when the timing is better, even after program completion.

Recommendation 5. Ensure sufficient technological maturity of products. Prototype demonstration, a common strategy at DARPA, is a logical way to improve maturity. Aided by the Agency's demand for demonstration, those products that successfully transitioned are surprisingly mature. But, many Agency customers have complained that DARPA tends to quit too early, well before a technology is ready to be incorporated into a military system. DARPA's technology offices may elect not to spend that much time on a technology, but they can transition it to a Service laboratory or continue working on it in one of their systems offices. At any rate, agreement should be reached on the TRL category for each product leaving the Agency.

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