IDA PAPER P-2444

THE FUTURE OF MILITARY R&D: TOWARDS A FLEXIBLE ACQUISITION STRATEGY

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July 1990

INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

Series B
IDA Log No. HQ 90-35752

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1990	

4. TITLE AND SUBTITLE

The Future of Military R&D: Toward a Flexible Acquisition Strategy

5. FUNDING NUMBERS

Independent Research

6. AUTHOR(S)

Paul Richanbach, Thomas Christie, Ronald Finkler, David Graham, Frederick Riddell, William Schultis, Edwin Townsley, Victor Utgoff

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311

8. PERFORMING ORGANIZATION REPORT NUMBER

IDA Paper P-2444

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The U.S. will have difficulty maintaining its technological superiority for future military systems, due to declining defense budgets, lower levels of production for weapon systems, and great uncertainty regarding future military requirements. What is needed is a military R&D system that generates technological options of sufficient quality and in sufficient numbers so that, in spite of the uncertainty they face, U.S. forces can be fully prepared to meet a wide range of contingencies. The paper explores the attributes of a "flexible acquisition strategy," in which numerous options would be explored from basic research (budget category 6.1) through advanced development (6.3A). Programs would enter full development (6.4) less often and more selectively, and not every 6.4 development program would be expected to reach production. The paper recommends and discusses seven actions that are important elements of a flexible acquisition strategy for R&D. DoD should: (1) reaffirm that maintaining superior technological options remains a vital strategic objective, (2) increase funding for science and technology (S&T), (3) treat R&D as a product in its own right, (4) increase the use of prototyping, (5) improve the development of technological options for modifying existing systems, (6) increase the use of commercially available technology, and (7) consider the need for mobilization in weapon system designs.

14. SUBJECT TERMS

Research and Development, Military Research and Development, Defense Industrial Base, Acquisition, Procurement, Defense Industry

5. NUMBER OF PAGES

34

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

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INSTITUTE FOR DEFENSE ANALYSES
IDA Independent Research Program

PREFACE

This paper was prepared by the Institute for Defense Analyses at the request of Dr. John Foster, Chairman of the Defense Science Board. Its purpose is to assist Dr. Foster and the members of the DSB in preparing for their summer study on the "DoD R&D and Investment Strategy." The paper seeks to develop a general framework within which, it is hoped, a fruitful debate can take place regarding the fundamental changes that must occur in military R&D in the months and years ahead.

The paper was prepared by research staff members Paul H. Richanbach, Thomas Christie, Ronald A. Finkler, David Graham, Frederick R. Riddell, William Schultis, Edwin Townsley, and Victor Utgoff. The authors benefited from reviews and comments of drafts provided by a number of other members of the IDA staff, including: General W.Y. Smith (President), Bob Roberts (Vice President, Research), Phil Major (Vice President, Planning and Evaluation), Seymour Deitchman, Stanley Horowitz, Richard Ivanetich, Terry Mayfield, Julian Nall, John Tillson, Robert Turner, and Richard Van Atta; and IDA consultants Barry Blechman and David Hardison.

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I. INTRODUCTION

The question facing the military research and development establishment can be stated simply: How can the U.S. maintain its technological superiority for future military systems, given declining defense budgets, lower levels of production for weapon systems, and great uncertainty regarding future military requirements?

The decline in the Soviet military threat, the increased attention being devoted to potential third world military threats, the increased military-technological capabilities of those potential threats, and the increase in uncertainty surrounding U.S. military needs and responsibilities will lead to dramatic changes in the size, structure, and capabilities of U.S. forces. The materiel and technology needs of the forces can therefore also be expected to change dramatically.

In addition to these changes in the military environment, the military research and development (R&D) establishment is being buffeted by a number of other, diverse forces. These include efforts to revamp--through reorganizations, consolidations, and more centralized management--a DoD laboratory system that is perceived to be broken; the overall pressure of reduced DoD budgets; and increasing demands that DoD contribute more to non-traditional missions such as improving U.S. economic competitiveness and environmental cleanup.

These observations lead us to conclude that the role of military R&D must change significantly in the years ahead. This paper proposes an overall strategy for military R&D that puts these changes into perspective and is consistent with the changing role of DoD. Specifically, for 45 years the U.S. has had a strategy of maintaining options to provide for technological superiority over a single, stable, and well-defined threat. We now need to alter this strategy to one of maintaining superior technological options that will support diverse capabilities against a much larger number of uncertain and ill-defined threats.

The U.S. needs a military R&D system that generates technological options of sufficient quality and in sufficient numbers so that, in spite of the uncertainty they face, U.S. forces can be fully prepared to meet a wide range of contingencies. This paper develops a strategy for meeting this need, and considers some of the implications of this strategy for the future conduct of military R&D. It seeks to develop a general framework within which, it is hoped, a more fruitful debate can take place regarding the fundamental changes that must occur in the military R&D and acquisition process in the years ahead. We refer to this new approach as a *flexible acquisition strategy.*

In this paper we address primarily the "front end" of the acquisition process, in that our focus is on the provision of technological options by the research and development program. We consider both the implications of changing R&D needs on the acquisition system, and the implications of a changing acquisition system on the conduct of R&D. We do not consider in any great detail the "back end" of the acquisition process: how to use the technological options that are available in making system and force decisions, what the forces should look like, how to make acquisition decisions, etc. Thus this paper is designed to help us move towards a flexible acquisition strategy--there are many other issues regarding such a strategy that remain to be worked out.

The flexible acquisition strategy we propose consists of seven primary elements. We first describe the overall framework for a flexible acquisition strategy, and then for each of these seven elements we provide a specific recommendation regarding what policy actions need to be taken. The rest of the paper then explores for each of the seven elements some of the key issues surrounding the recommendations.

Some of the elements of the proposed strategy reaffirm basic principles for R&D that have been advocated repeatedly in the past. For example, we call for an increase in prototyping, which many groups and individuals have advocated for decades. We believe, however, that the numerous changes that have taken place in the security environment during the past year or two provide an even more powerful rationale for these recommendations, and they must now be taken more seriously. Furthermore, taken individually, it has been much easier to ignore or dismiss the importance of these ideas. We provide a new framework for considering all of these recommendations together, which results in a far more powerful argument for taking dramatic action to change the future course of military R&D.

II. OVERVIEW OF A FLEXIBLE ACQUISITION STRATEGY

A. Introduction

The current acquisition process can be characterized as a pipeline.[1] We enter one end of the process with research and development, and then produce and field specific weapon systems at the other end. Once a decision has been made to develop technology to produce a specific system--and this decision occurs very early in the pipeline--that system is almost a sure thing to come out the other end in production. That is to say, once a system passes Milestone I in the acquisition process, it is a virtual certainty that it will enter production several years later. The primary characteristic of this pipeline, then, is that there is a filter very early on that, once passed, virtually guarantees the system's journey through to the other end of the pipeline and eventual production.

It could be argued that such a process makes some sense if one faces a stable and well-defined threat. The new environment we are entering is characterized by less well-defined, less stable, and more widespread threats. It is a world characterized by great uncertainty over missions, force capabilities and force structure requirements, and specific weapon system needs. Moreover, given limited budgets, the range of new systems that can be deployed will be more limited. We conclude that mission uncertainty, budget limitations, and the need for system and force flexibility, require a flexible acquisition strategy.

Under a flexible acquisition process, a decision early in the pipeline to proceed with a set of technologies or a system concept would not constitute a determination that a specific system would, in fact, go to full scale production. Rather, there would be a number of filters or valves through which technologies and systems would have to pass before a production decision would have to be made. In addition, technological developments in sub-systems and components could be available for introduction into existing systems (product improvements) without having to commit to a new system entering production. The R&D and acquisition process would be geared to four major types of developments: (1) modification to existing equipment in the field, (2) improvements to and modernizations of systems currently in production, (3) new product developments, and (4) designs and design modifications which allow for rapid production in the event of a mobilization.

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1 For a complete treatment of this idea see Ted Gold and Rich Wagner, "Long Shadows and Virtual Swords: Managing Defense Resources In the Changing Security Environment," April 1990.

By adopting such a process, DoD would be moving towards the commercial model, in which R&D, design, development, prototyping, and production decisions are continuous and evolutionary. New product introductions representing real discontinuities rather than evolutionary product improvements would not occur unless and until a major new technology opportunity and "market" need arose. The underlying philosophy of this more flexible acquisition process would be to provide the armed forces with as many technology and acquisition options as possible, without having an R&D process that is too focused on new starts and the complex procedures required to bring the new system into production. This model is consistent with the Packard Commission's recommended approach, which emphasizes the importance of early design and prototyping efforts.

Under a flexible acquisition strategy, numerous options would be explored from research (6.1) through advanced development (6.3A). Programs would enter full scale development (6.4) less often and more selectively, and not every 6.4 development program would be expected to make it into production. This strategy raises important issues regarding the proper balance between research, development, prototyping, and production. If fewer products are to be delivered to the users because of reductions in acquisition budgets, increased attention will have to be paid to modifying and modernizing existing systems. Finally, cost considerations, the availability of advanced technology, and the desire for an industrial mobilization capability should drive DoD towards the greater use of commercially available technology.

B. Recommendations

Adopting a flexible acquisition strategy requires a number of important policy changes. As we noted above, many of these changes have been discussed in one form or another, some of them (e.g., prototyping, the use of commercial products and procedures) for many years. We are suggesting that when these and numerous other ideas are considered within the context of a new, flexible acquisition strategy--and in the context of lower force levels and budgets--they take on a far more powerful logic than when considered individually.

We recommend that the following actions be taken in order to put into place a flexible acquisition strategy. In the remaining sections of the paper the rationale behind each of these recommendations is presented.

> **Recommendation 1:** *DoD should reaffirm that maintaining superior technological options remains a vital strategic objective.* At the same time it must be understood that maintaining superior technological options in the face of diverse and uncertain

threats requires a far different approach to military R&D than doing so in the face of a single, stable, well understood threat.

Recommendation 2a: *Funding for science and technology (S&T) should increase.* S&T (budget categories 6.1, 6.2, 6.3A) is not synonymous with R&D (which includes 6.3B, 6.4, and 6.5). Funding for S&T and for the development of other non-system specific technological options (some 6.3B spending), should increase, even as the remainder of the R&D and acquisition budgets decline.

> **Recommendation 2b:** *The DoD science and technology program and laboratory system have fundamental management problems which must be addressed immediately.*
>
> **Recommendation 2c:** *DoD's R&D resources should remain focused on military needs.*

Recommendation 3: *DoD should treat R&D as a product in its own right.* Particularly in its dealings with the defense industry, R&D funds for new programs should not be tied so closely to the prospects for the future production of a system.

Recommendation 4: *Increase the use of prototyping.* Prototyping is broadly defined here to include technology demonstrators (including Advanced Technology Transition Demonstrations--ATTDs), product improvement prototypes, and other efforts short of, as well as including, pre-production prototypes.

Recommendation 5: *Improve the development of technological options for modifying existing systems.* A systematic approach should be taken to developing larger numbers of technological options which would extend the capabilities and operational lives of systems already in the field.

Recommendation 6: *Increase the use of commercially available technology.* DoD must learn to take greater advantage of commercial technology, both domestic and foreign, including manufacturing technologies.

Recommendation 7: *Weapon system designs must consider the need for mobilization.* Because strategic warning for a major conflict is likely to increase significantly, increased attention should be given to designing weapon systems that can be rapidly manufactured in the event of a mobilization.

III. THE KEY ELEMENTS OF A FLEXIBLE ACQUISITION STRATEGY

A. The Importance of Superior Technological Options

1. Technological Superiority, Technological Options, and Appropriate Technology

Recommendation 1: *DoD should reaffirm that maintaining superior technological options remains a vital strategic objective.* At the same time it must be understood that maintaining superior technological options in the face of diverse and uncertain threats requires a far different approach to military R&D than doing so in the face of a single, stable, well understood threat.

The U.S. armed forces have a responsibility, in support of U.S. national security objectives and diplomatic efforts, to continue being prepared for a wide range of contingencies throughout the world, including the need to deter the Soviets from attempting to use their still substantial military capabilities to resolve contentious issues in their favor. Our strategy for meeting these responsibilities has included, as a central tenet for many decades, the importance of maintaining qualitative superiority over potential adversaries. This qualitative superiority is expected to result from a number of factors, including superior training, support, and weaponry, each of which depend heavily on weapon system designers having access to a wide range of technological options.[2]

Now that we are moving headlong into efforts to reduce military forces and tensions, we may be tempted to believe that (a) maintaining our technological options is no longer as important as it once was, or (b) we can maintain those options on the cheap, by reducing funding for science and technology efforts. These temptations must be resisted: so long as the U.S. has responsibilities which require the maintenance of armed forces, the overall quality and capabilities of those forces should be the best that we can attain; and it is not the case, as we shall argue below, that these options can somehow be maintained without continuing to invest adequately in the technology base. This is the only way of ensuring the forces we need will have access to the full range of technological options that may exist. Of course we must recognize that the changing nature of the threat--particularly the increased uncertainty due to multiple and changing threats--will require a different set of technological options than in the past.

This argument for the retention of superior technological options as a cornerstone of U.S. military strategy should not be interpreted as a blind endorsement of technology for its own sake. In particular, a distinction needs to be made between the most sophisticated technology and that technology which is most appropriate for the job. Having a wide range of technological options to draw from will continue to be important. However, all too often in the past we have taken the highest technology available and applied it towards a particular mission with insufficient regard for whether this application (a) provided the forces with the best ability to perform all of their missions, or (b) represented the optimal cost-performance tradeoff.

With regard to the first point, numerous examples can be cited in which the available technology was not appropriately applied to an important mission. In fact, everywhere U.S. forces have fought since World War II--from Korea and Vietnam to Grenada and Panama--problems have arisen because important items of equipment and elements of force

2 The term weapon system should be understood to include the full range of military systems and capabilities, including, for example, combat casualty care and logistics.

structure were designed primarily with a different mission in mind; i.e., defending against a sophisticated, heavily armored Warsaw Pact attack in central Europe.

While we recognize that designing forces and weapon systems ideally suited to every possible contingency is impossible, we would also suggest that U.S. forces must be far more able to fight under a wide range of circumstances than they have been in the past. This is precisely the challenge posed by the increased uncertainty over who and how capable our potential adversaries will be. Although the price of flexibility is that one may never be suited ideally to fight a particular foe, the price of inflexibility is to be suited inadequately to fight all but one or a handful of potential adversaries.[3] Somehow we must strike a better balance between these two obvious facts.

A good example of this problem is provided by the services' experiences with unmanned air vehicles (UAVs). In this case, all three services have had legitimate technical difficulties in designing UAVs that can withstand the very hostile environment expected to be encountered in a major conflict with the Soviets in Europe. At the same time, however, they gave little consideration to the development and employment of UAVs that could operate in the less hostile environments to be found anywhere else in the world. Consequently, for example, the Navy found itself, off the coast of Lebanon in 1983, using F-14s for reconnaissance missions and attack aircraft for bombings, when UAVs could have provided much of the same reconnaissance or could have spotted for the large guns on the battleship off shore. Because the guns on the battleship were largely ineffective, manned aircraft had to perform bombing missions, some of which could have been avoided had UAVs been available. This is a classic example of how the most appropriate technology, while not always the most sophisticated, might have improved mission performance and saved lives.

With respect to the second issue--cost-performance tradeoff decisions--there is a strong bias on the part of the armed forces to demand that each individual piece of equipment possess the most advanced technology available. But pushing the performance envelope the last 5 or 10 percent is widely believed to result in system cost increases of up to 30 percent or more. In addition to the question of whether this last ounce of capability is worth the extra price, one must also question whether the right trade-offs are being made between individual effectiveness and the effectiveness of larger force units. Is the right

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[3] One sign of the changing times is that the Army now plans to increase the amount of R&D it spends on light forces, at the expense of heavy forces, in recognition of the changing demands that will be placed on it in the years ahead.

tradeoff being made between the capability of a system, the numbers that can be produced, and the ability of the forces to perform their mission given the quality and numbers of these systems that they have been supplied?

Although our forces will be much smaller, they will be called upon to face a wider range of contingencies. Force planners will be required to structure forces under circumstances of far greater uncertainty than at any time in the past. Consequently, force planners will have a wide range of needs that could change quickly, and may often find themselves with forces and systems that are not ideally suited to the exigencies of the moment. The challenge for the military R&D system is to ensure that force planners have the full range of technological options from which to choose at any time. To meet this challenge, we believe that some fundamental changes must be made in the weapons acquisition process. This process must move in the direction of what we and others are calling a flexible acquisition process.

2. Technological Superiority vs. Spurring the Arms Race

The strong military research program needed to minimize the chances that a potential opponent can obtain a decisive advantage in military technology seems likely to run into increased political opposition. Influential people will argue that continued emphasis on research into new technologies for military application is no longer needed now that the cold war is over; has the adverse effect of spurring suspicions about the long-run intentions of the U.S.; and will create new military-related technologies that will eventually find their way into military competitions in the third world, if not into a renewed competition between the major powers.

There are a variety of approaches for dealing with such concerns. First, it is important to remind critics that advances in military technology have led to decisive changes in the security of nations on many occasions (e.g., radar, jet aircraft, nuclear submarines, the atom bomb). Second, it may be useful to further limit access to information on U.S. military research, particularly into technologies that seem best suited to support relatively offensive strategies and doctrines.[4] Third, while no military capability can be argued legitimately to be purely defensive or purely offensive, it may be possible to emphasize research on military technology that has the potential to be of greater value to defenders than attackers. Finally, maintaining better intelligence on other countries' military-related

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[4] This particular suggestion is obviously controversial, and is not one on which the authors are in agreement.

research will be critical, particularly as the reduction in forces in-being offers increased opportunities to exploit dramatic improvements in military applications of new technology (this is discussed more in the next section).

In summary, there will be arguments for increased research into military-related technology to guard against the increased dangers of technological surprise that come with reductions in forces in-being, and against such research as inappropriate to the times and likely to lead to new arms races. Policies for heading off and dealing with this increased controversy over DoD research efforts must be thought through now.

3. Doctrinal Implications of New Military Technology

All other things being equal, as forces in-being are reduced, the potential impact of modest numbers of new military systems employing dramatically improved technology will increase. In addition to placing a premium on being the first to discover new technologies with possible military applications, it will be increasingly important to develop a sound appreciation of how new technologies can be applied, not just to increase capabilities to execute existing military doctrine, but also to implem wholly new concepts of warfighting.

History has demonstrated repeatedly that new military systems can have dramatically different values for armies that adapt their doctrine to take full advantage of them. A good example was provided by the Battle of France in 1940, in which the enlightened use of the tank by the German army was a decisive factor in defeating a larger French army with roughly comparable numbers of what were, in some cases, technically superior tanks.[5]

The above arguments imply that the increased emphasis to be placed on research into new military technologies should be paralleled with increased emphasis on understanding the changes in warfighting doctrine that new military technologies can imply. The greater use of innovative simulations and field exercises with prototypes will play an important role here.

B. The Science and Technology Program

1. Funding Issues

Recommendation 2: *Funding for science and technology (S&T) should increase.* S&T (budget categories 6.1, 6.2, 6.3A) is not synonymous with R&D (which

[5] In fact, ongoing studies at IDA suggest that we can expect that the associated doctrinal adjustments will often be the primary determinant of whether or not a new military technology will prove decisive.

includes 6.3B, 6.4, and 6.5). Funding for S&T and for the development of other non-system specific technological options (some 6.3B spending) should increase, even as the remainder of the R&D and acquisition budgets decline.

Science and technology (S&T) is not synonymous with research, development, test, and engineering (RDT&E). S&T--budget categories 6.1 (Research), 6.2 (Exploratory Development) and 6.3A (Advanced Development)--amounts to about 5 billion dollars per year (excluding research funded separately by the Strategic Defense Initiative Organization), or 14 percent of the approximately 38 billion dollars spent annually on RDT&E. S&T constitutes less than 5 percent of procurement plus RDT&E (about 120 billion dollars) and less than 2 percent of the entire DoD budget. Most of the S&T budget is spent either directly by the DoD laboratories or through contracts administered by them with researchers in universities or private industry.[6] The remaining 86 percent of the RDT&E account, most of which funds full scale engineering development efforts for specific systems, is divided between private industry and the DoD laboratories, with the majority of the funds spent by industry.

Like any other public or private organization dependent upon advanced technology, DoD requires an in-house R&D capability that allows it to keep abreast of what is going on in the world and to adapt those developments to its own needs. There are many unique military applications for technology that require an independent DoD laboratory system. In addition, a DoD laboratory system is necessary to maintain effective communication between the providers of technology (the laboratories themselves and industry, many of whose efforts the laboratories oversee) and the military users of technology (the developers of systems requirements).

Adopting a flexible acquisition strategy will increase the demands on the science and technology program, and therefore on the DoD laboratory system. Not only will there be a net increase in effort required, due to the increased use of technology demonstrators (see recommendation 4, concerning the increased use of prototyping), but the wider range of missions, for which U.S. forces will have to be prepared, will require a wider range of technological options from the science and technology program. Moreover, reductions in independent research and development (IR&D) funding for industry (primarily out of the procurement account, but with some support from R&D) may have to be made up in part through the science and technology program. Reductions in industry R&D spending

6 The term laboratories, as used here, includes laboratories, centers, and other DoD facilities that perform military R&D.

(currently about 40 percent of the total) may also have to be replaced by direct DoD funding.

The acquisition budget is driven largely by new starts and by the length of production runs. The S&T portion of this investment, which provides the flow of technological options, is relatively small. It is also independent of how many of these options actually enter full scale development and production. Consequently, if a steady flow of technology options is to be maintained, S&T funding should be protected, and not allocated as a "fair share" of the investment accounts. Other portions of the R&D budget--those tied directly to a specific weapon system or product--will, and should, decline, since these expenditures are roughly proportional to the investments in specific systems. These decreases will be far more than enough to offset the needed increases in funding for S&T. At the same time that its budget must be protected, the management of the science and technology program and of the laboratory system, which is responsible for conducting or overseeing most S&T activities, must be improved dramatically.

2. Management Issues

Recommendation 2a: *The DoD science and technology program and laboratory system have fundamental management problems which must be addressed immediately.*

There are a number of long recognized, serious problems with the laboratories, including unnecessary and wasteful duplication of effort, numerous management problems, concerns over the quality of personnel who are attracted to and retained by the laboratories, and so on. There is widespread agreement on the need to improve the efficiency of the laboratory system. The recommended changes fall into three broad categories.

The first is the need to draw on the recommendations for improving laboratory management that have been made by numerous studies in the past. The Defense Science Board, among others, has issued several reports detailing the problems of the laboratories and providing specific recommendations for improving their management. It is time to stop studying this problem and start implementing significant reforms.

The second set of recommended changes involves the consolidation and reorganization of the DoD laboratory system. OSD is currently conducting a laboratory consolidation study that is expected to have a considerable impact on the number of laboratories that will remain and the allocation of responsibilities between them. This is an important and overdue effort, but it should be conducted in the context of an overall strategy for the proper role of military R&D in the acquisition process, such as is suggested in this paper. If this were done, it would then be far easier to make decisions on which laboratories were doing good work and should continue to be funded, and which ones could be closed. We view with great concern proposals to centralize the management of R&D in OSD, and believe that what is really called for is better strategic direction and management oversight from OSD. This brings us to a third category of recommendations for improving the laboratory system.

To make the science and technology program more effective and relevant, senior managers in OSD (and the services) must be able to provide strategic direction and then cause the laboratories to comply with that direction. There is, however, a big difference between centralized management and centralized strategic direction. Strategic direction provides decisions on how much effort to devote to what broad purposes (including what not to do) and uses the authority to cut off funding as an enforcement mechanism. Centralized management involves the care and feeding of staff, the provision of facilities and support, quality control, financial management, etc. Recognizing this distinction, it is clear that more strategic direction, and not centralized management, is needed from OSD.

The services and agencies themselves recognize the need for OSD to take on a stronger role in this regard; in 1988 a specially convened task force of senior officials from OSD, the services and defense agencies, and the private sector, made a number of recommendations in an effort to make this happen. These recommendations would have set up mechanisms by which OSD could provide strategic direction to the services and agencies, and then follow up that guidance to ensure that the service and agency programs carried out this guidance faithfully. Although there is now a "DoD Science and Technology Program Investment Strategy," the other recommendations of this task force have not been adopted, and OSD is still widely viewed as unable to provide the kind of direction and leadership that the military services need and want.[7]

Finally, centralizing the management of the laboratories runs counter to widely accepted management practices that stress decentralized management structures in which senior (central) management is kept small and limits itself to the development and implementation of strategic direction. There is no substitute in any organization for strong and effective leadership from the top, and this is the primary need in DoD. Budget and efficiency needs will rightly force the closure and consolidation of many laboratories, and every effort should be made to do this as effectively and painlessly as possible. However,

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7 See Riddell, Frederick R., et al., eds, "Report of the Task Force for Improved Coordination of the DoD Science and Technology Program," IDA Report R-345, August 1988.

closures, consolidations, and reorganizations will not solve underlying problems of poor management practices and inadequate central direction and leadership.

While the laboratories are clearly in need of significant reorganization and management improvements, they still have a critical role to play in the future. In fact, the inevitable decline in the defense industry will increase the importance of having an effective DoD R&D establishment, at a time when defense research could become less prestigious, both in industry and government. While this highlights the importance of managing the laboratory system effectively, DoD and Congressional policy makers should resist the temptation to do away with, or fundamentally reorient, the laboratory system.

3. Technological Spinoffs To the Commercial Sector

Recommendation 2b: *DoD's R&D resources should remain focused on military needs.*

For several years the defense community has debated the proper role of DoD in fostering technological and economic developments in the commercial sector of the U.S. economy. Many argue that DoD can and should play a leading, or at least significant, role in helping the U.S. regain its economic competitiveness in the world economy. Senior policy makers in DoD and the White House have, for the last decade, taken the view that such an approach constitutes an explicit form of industrial strategy, which they, and many others, reject out of hand.

In considering this matter, it is important to distinguish between the potential for technological spinoffs from defense activities, and investments directed explicitly at promoting economic results that are not of direct importance to DoD research and development needs. While it is important for DoD to make a concerted effort to provide the commercial sector with the benefits of its technological developments, DoD's R&D resources should remain focused on military needs. DoD has many legitimate needs and uniquely military applications that the laboratories are chartered to satisfy, and this should remain their primary function.

If increases in government-supported R&D are desired for space, transportation, energy conservation, the environment, etc., then the government should invest new funds where they will have the highest payoff; it is unlikely that DoD laboratories will normally be the most efficient source for civilian research needs. If, for example, the U.S. wishes to invest more in environmental research, then it should provide additional funds to the Environmental Protection Agency (not DoD, which has far less expertise in this area) to invest in the most appropriate places. If some of those places turn out to be DoD laboratories--if DoD laboratories can compete with other providers of environmental research--then it may be appropriate to allow them to do so. In other words, federal monies should be allocated on as competitive a basis as possible to those organizations--public or private--which demonstrate the best capability to address the specific problems the government wishes to solve. If some DoD laboratories are no longer needed to perform military R&D and are unsuccessful in competing for other resources, they should be closed.

Another consideration concerning the DoD laboratories is that there is a difference between programming or planning for the laboratories to do civilian research, and simply allowing them to do it or encouraging spinoffs to the private sector. It may not be a good idea to allow the laboratories to broaden their charters to do a significant amount of non-defense work. The concern is that this could lead them too far from their primary mission of supporting DoD and its unique military requirements.

Finally, arguments to the effect that the DoD laboratories are a national asset, which should somehow be used to solve other national problems, are often thinly veiled arguments for keeping specific facilities funded. While pork barrel politics is a long-standing fact of life, we should not allow these rationalizations to substitute for a meaningful debate on the appropriate role of the laboratories.

C. Treating R&D As A Product

Recommendation 3: *DoD should treat R&D as a product in its own right.* Particularly in its dealings with the defense industry, DoD should not continue to insist that R&D funds for new programs be tied so closely to the prospects for the future production of a system.

We need to face the fact that the defense industry will shrink in the future. Rather than spending an inordinate amount of time and effort in resisting the inevitable, DoD should shape policies to make this happen as smoothly as possible. With the declining demand for production, research and development will have to become a product in its own right. Until now the R&D money for new programs has typically been tied to the prospects for future production. These funds will be less available in the future as industry cuts back on R&D investments for which they see declining prospects for eventual payoffs (i.e., production contracts), and as DoD cuts back on specific programs and the R&D tied to those programs.

Of particular significance here will be the potential for large cutbacks in the multi-billion dollar Independent Research and Development (IR&D) program. If cutbacks are made in the IR&D program--which is funded primarily out of the procurement account, as well as the non-technology base portions of the RDT&E account--it may become necessary for DoD to increase the amount of funds provided to industry through the science and technology program (specifically, 6.2 and/or 6.3A). This raises the entire issue, however, of whether and how to maintain government-funded, but independent, industry research. New mechanisms for carrying out such research may have to be devised in the years ahead.

Clearly, DoD must change the incentive structure it maintains for industry and allow for sufficient profits to be made directly on research and development. This transition on the government side will likely be difficult given current DoD regulations, the need to avoid creating a program full of "pet rocks," the risk-averse nature of the acquisition culture, and the resistance of that culture to change. At the same time there is little doubt that industry can provide the research and development DoD needs. Not only does a large portion of the industry already treat R&D as a product for at least some of the work it does, but this way of doing business was common in the 1950s and early 1960s. (Prototype development was also more common during those years, a subject to which we turn next.) What is needed is a willingness on the part of DoD to contract directly for R&D in a way that maintains industry's incentive to continue performing it.

D. Increased Use of Prototyping

1. The Role of Prototyping

Recommendation 4: *Increase the use of prototyping.* Prototyping is broadly defined here to include technology demonstrations (including Advanced Technology Transition Demonstrations--ATTDs), product improvement prototypes, and other efforts short of, as well as including, pre-production prototypes.

Prototyping will play an important role in a flexible acquisition strategy. Prototyping represents the logical extension of the premise that the R&D process should provide the armed forces with options from which to make weapon system and force structure decisions. Prototyping in this context mean technology demonstrators (including Advanced Technology Transition Demonstrators[8]) and other prototypes that explore and demonstrate particular technical concepts, not just pre-production items manufactured in full scale development (FSD) to iron out technical and manufacturing problems prior to the start of full scale production. We also have in mind the prototyping of components and

8 A major feature of ATTDs is testing in an operational rather than a simulated environment.

subsystems for product improvements of existing systems, as well as prototypes of new system concepts.

Prototyping takes on even more importance as we face an increasingly diverse set of military threats. We cannot build everything we would need in order to be ideally suited to handle every possible contingency. We can, however, maintain a sufficient number of live options so that, as the military and threat environment evolves, we are in a better position to build the kinds of systems we need relatively quickly. This means, however, that we will not build everything--some R&D will never get used in a system. Such R&D will still have performed a useful function, however, as a hedge against uncertainty. The old argument against prototyping--that we do not want to build something we won't use--is no longer applicable when prototyping is properly understood in the context of a flexible acquisition strategy.

Increasing the emphasis on prototyping raises a number of difficult issues, including how often designs get prototyped and how to structure the competition between competing designs. DoD must also be concerned with what R&D capabilities will remain as industry shrinks. In particular, DoD must ensure that its actions do not result in an unacceptable loss of specialized design teams in key industries. In addition to research teams, a viable number of design teams must be maintained to retain the diversity of approaches necessary for the competitive generation of defense systems.

Various approaches will have to be used because the effects of reduced acquisition budgets on the large systems integration firms will be quite different from those on equally important second and lower tier equipment firms. It is generally agreed, however, that in order for design teams to remain effective, they must work on real systems that are actually built and tested. Consequently, since the number of different systems entering production will decline, the importance of providing design teams with an opportunity to build prototypes will increase substantially.

2. The Potential Impact of Longer Design Periods

One byproduct of increasing the use of prototyping and having fewer systems in production will be an increase in the amount of time between production decisions for weapon systems, and thus an easing of the time pressure to attain an initial operating capability (IOC). In other words, a system or sub-system might be designed, but a decision may be made to hold off on its production. This would provide a longer window of opportunity to mature the design and test it in realistic operational environments, and could allow for greater attention to producibility, maintainability and other manufacturing and support considerations. To put it another way, by easing the time pressures faced by designers, increased attention could be placed on reducing the eventual cost of a product. At the same time, with existing systems staying in the field longer, increased attention could be paid by designers to cost effective means of introducing product improvements.

3. Meeting Military Needs

Finally, a perennial problem with military R&D has been ensuring that it is focused on meeting the true needs of the forces in the field. Ideas that seem great in the laboratory may be of little value on the battlefield, because they take insufficient account of the complex needs of the user. Prospective weapon systems and concepts need to be employed and evaluated by the using forces, where tactics can be developed and practiced and improvements can be made by the R&D and design communities based on their experiences. An R&D and acquisition system which has fewer new starts could conceivably exacerbate the problem of communication between designers and users, by serving to further break the link with the forces in the field.

Aside from recognizing its importance and continuing to foster improved communication between the R&D community and the users, this problem can be addressed in two different ways. First, increasing the use of prototyping will provide a mechanism for evaluating the potential effectiveness and shortcomings of technologies, components, and sub-systems before they are accepted for production. These prototypes could be evaluated by special "R&D units" established to evaluate prototypes and other new ideas, and by actual operational units in the field. Second, advanced simulation and other technologies make it possible to test ideas in far more realistic and effective manned simulators and wargames than in the past. These technologies can be used to test proposed changes in components, subsystems, or systems before complete prototype systems are constructed, saving considerable time and expense.

E. Extending The Capabilities of Existing Systems

Recommendation 5: *Improve the development of technological options for modifying existing systems.* A systematic approach should be taken to developing larger numbers of technological options which would extend the capabilities and operational lives of systems already in the field.

We have argued that the exploration of technological options need not have as its ultimate goal the development and production of a completely new system. Rather, the R&D process should also be oriented toward providing capabilities which can be used continuously to improve the performance and extend the useful lives of existing systems.

This applies to both component and subsystem replacement on systems already in the field (retrofits and modifications), and design changes to upgrade and modernize systems currently in production. A further implication of this approach is that, even when a new system is being designed, every effort should be made to make its components and subsystems compatible with the system it is intended to replace. This is common practice in the commercial sector, and should be adopted as common practice by DoD.

In fact, the lower turnover rate of new equipment caused by declines in acquisition budgets automatically implies the need to increase investments in upgrades and product improvements. There are many examples of how this is currently being done (the B-52 program, engine extension programs), but greater attention will have to be paid to designing more efficient capability upgrade and life extension programs.

The following example shows just how strongly the acquisition culture resists the approach we are suggesting. The Air Force is developing new engines for its proposed advanced tactical fighter (ATF) aircraft. Several Air Force officers are reported to have put their careers on the line some years ago by insisting that these engines be designed so that they could be used by existing F-15 and F-16 aircraft. It is fortunate that they prevailed, because F-15s and F-16s will be in the inventory for many years to come, and will now be able to benefit from these engines; and because the ATF could now be delayed for years or even cancelled, and the billions of dollars spent on its engine development program would then have been wasted.

F. Increased Use of Commercial Technology

Recommendation 6: *Increase the use of commercially available technology.* DoD must learn to take greater advantage of commercial technology, both domestic and foreign, including manufacturing technologies.

DoD must increase the use of commercial technology in the design and development of weapon systems. Although this has long been suggested by many people, there are now two additional reasons why this should become an important element of an R&D and acquisition strategy. One has to do with the sources of technological advance, and the other with the economics of weapons procurement.

A recently issued report, "New Thinking And American Defense Technology," by the Carnegie Commission On Science, Technology, and Government begins by noting that

> the American dominance of virtually all fields of technology--and especially defense technology--during the post-war period is giving way to a position of first among equals.

The Defense Department consequently must learn how to share in technological advance wherever it takes place, whether in the nondefense sector or in other countries.[9]

The weapons acquisition process in the Department of Defense is built on the premise that DoD is a net source of technology to the rest of the U.S. and world economies. Twenty-five years ago this was not an unreasonable assumption, but today DoD is a net recipient of technology. A generation ago, DoD research and development into and purchases of computers and semiconductors were very important to the development of those technologies and industries. Today, DoD design procedures, development efforts, and procurement regulations actually inhibit, in some cases, the use of advanced technological developments from these same industries, which are now ahead of DoD in a number of important technologies. How far DoD can go in adopting commercially available technology to its needs is unclear, but it is clear that DoD has a long way to go from its current practices, which virtually guarantee defense products that are incompatible with technologies and production methods available commercially. Unless it reverses this practice, DoD will find itself unable to take advantage of many civilian technological advances with potentially important military applications.

The second reason why DoD must learn to increase its use of commercially available technology, including manufacturing technology, is that this may be the only way it can afford to design and build high quality systems in the future. The current system of designing, developing, and manufacturing weapon systems is so inefficient--because of the need to maintain large industrial facilities that have no other function, the very low quantities that are involved, and the insistence on developing and using very specialized technology and other products--that the costs of many systems may finally become too painfully high for the Defense Department to bear. At the same time, developments in the private sector, including flexible manufacturing technologies and rapid prototyping capabilities, may make the use of commercial technologies, products, and processes an increasingly plausible and economical alternative.

There are several other reasons to consider adopting commercially available technologies. One is that, as the defense industry shrinks, there is evidence that some of the most capable firms may be leaving the industry. Some argue that those firms that are least able to survive in the non-defense marketplace because they lack the necessary technology and products, are precisely the ones that are staying behind, because they have

9 The Carnegie Commission On Science, Technology, and Government, "New Thinking And American Defense Technology," May 1, 1990, p. i.

nowhere else to go. If DoD wishes to continue having access to firms with leading-edge technology and products, it may have to learn to act like other commercial customers. This issue is far from resolved, however--no doubt many firms are remaining in the defense industry because they are confident of their ability to remain competitive in a shrinking market. This is an important issue that DoD acquisition and industrial base policy makers should explore before it becomes to late too take corrective action.

Yet another reason for adopting the capability to use commercially available technology is that the movement by U.S. forces towards lighter forces, counter-insurgency operations, and so on, brings with it a demand for equipment such as communications and lighter vehicles that may be more readily producible with commercial components and by commercial methods than some of the equipment associated with heavier forces. A final reason is that this is the only way the U.S. will ever develop a satisfactory industrial mobilization capability. An important issue which will have to be resolved in this context is the degree to which the U.S. should rely on foreign-sourced technologies and products, and how it should hedge against the potential for denied access to those technologies.

G. Designing for Industrial Mobilization

Recommendation 7: *Weapon system designs must consider the need for mobilization.* Because strategic warning for a major conflict is likely to increase significantly, increased attention should be given to designing weapon systems that can be rapidly manufactured in the event of a mobilization.

In a world in which we and our adversaries have much smaller standing armed forces, the strategic warning time available for large scale military actions could increase to two or more years. In combination with a force structure consisting of smaller standing forces and a much smaller defense industrial base, this makes the question of industrial mobilization far more important and, in fact, more interesting than it has been for most of the cold war era.[10] Perhaps the most important implication is that mobilization potential will depend on the ability of the civilian industrial base to shift quickly to the large scale production of military systems. This, in turn, will require that military systems be designed so that they are, in fact, producible by the civilian economy, which they currently are not (as was discussed above).

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[10] Because strategic warning, until now, could be measured in days and weeks, senior policy makers have been unwilling to take seriously the notion of industrial mobilization, which would have little effect for months and years after the beginning of a conflict. If, in the future, strategic warning can also be measured in years, then the notion of mobilization should become plausible to these decision makers, and should begin to influence force structure and acquisition policies.

The desire to increase the economy's mobilization potential could, however, be complicated if a decision were made to move toward a force structure consisting of small numbers of very highly capable units. If the defense industry is asked to design and produce small numbers of highly sophisticated systems, it may be more difficult to ensure that the civilian economy can contribute to the production of these systems.

There are two ways out of this dilemma. The first is to insist that designated weapon systems be designed to be produced with the technology, products, and manufacturing methods available in the commercial sector. The second is to design and have available "force augmentation" weapon systems designed explicitly for large volume production and use by mobilized forces. Such systems might well have to be less capable than those made available to the active forces. In other words, U.S. forces would have to consist of very highly capable active forces and, in the event of a major conflict, less capable but larger augmentation or reconstitution forces.

There are those who argue that designing commercially compatible weapon systems is not only preferable, but also technologically possible, if only DoD would alter its procurement regulations (see the previous section on increasing the use of commercial technology). In particular, many feel that modern flexible manufacturing techniques have fundamentally altered the way in which we should view the manufacture of weapon systems. Others argue that this is an overly optimistic view of both the ability of commercial industry to manufacture sophisticated defense systems, and the ability of the procurement system to alter its culture. Moreover, it will require the Services and CINCs to develop doctrines for employing "force augmentation" weapons. In this regard, one cannot ignore the fact that efforts to design weapons that can be manufactured by civilian industries runs against 45 years of a trend toward specialized defense manufacturing; implementing this element of a flexible acquisition strategy would be complicated in the extreme.

IV. CONCLUSIONS

The changed national security and budgetary environment will result in smaller forces and less investment in weapon systems. These factors require that we rethink our approach to the conduct of R&D, its role in the acquisition process, and our approach to the entire acquisition process itself. We have suggested that a "pipeline" mentality, in which R&D leads inexorably to the production and fielding of a system, must be replaced by an options mentality, in which there is a far greater emphasis on making evolutionary improvements to existing (fielded) systems. We have made a number of specific recommendations regarding the framework for the R&D and acquisition process we have in mind, which we call a flexible acquisition strategy.

Budgets, force levels, production, and public support for investments in weapons and military R&D will continue to decline. Senior leaders in DoD, the administration, and the Congress will soon be called upon to make far-reaching decisions on the future of military R&D, and of the entire acquisition process. The proposals we make here are an attempt to provide those leaders with some specific ideas and concepts upon which to base those decisions.

DoD must take action to create a new system, and not attempt to patch up the old one. (Efforts such as the rewrite of DoD Directive 5000.1, the lab consolidation study, acquisition streamlining, and so on should be held up or reconsidered in this light.) If DoD does not succeed in getting its own house in order, others will surely try to do it for them. The dramatic changes we face represent opportunities, but we must start now if we are to take full advantage of them.