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DISSERTATION

Fundamental Capability Portfolio Management

A Study of Developing Systems with Implications for Army Research and Development Strategy

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Summary

Over the past years, the United States Army has faced an increasingly austere budgetary environment of unknown duration. At the same time, in the future the Army must prepare for a more diverse, burdensome and uncertain strategic environment, from conventional warfare to counter-insurgency. Anticipating these constraints, in 2006 the Department of Defense (DoD) mandated the use of capability portfolio management in acquisitions, to ensure that an efficient mix of systems is being developed and fielded within strict budgetary limitations. However, a lack of research in two important areas is constraining the ability of the Army to perform effective portfolio analyses. First, there is limited research to help the Army perform specific portfolio analysis and assessment of this kind. Second, for individual systems within a portfolio, a body of research has documented the extent and causes of cost growth, schedule delay, and cancelation in 'major weapon systems', but relatively less attention has been paid to the smaller, less expensive systems that actually make up the majority of the Army's budget.

A growing literature has begun to establish a framework for portfolio analyses involving military systems. These studies have often focused on project selection either within a capability requirement area, which groups systems within a very broad category, or across such broad categorical areas. A capability requirement area actually contains multiple systems serving very different specific functions at a more fundamental, basic level. For example, 'Lethality' is one traditional capability requirement area defined by the Army as the ability to destroy or neutralize adversaries. The lethality requirement needs to be accomplished in a myriad of different ways depending on the situation by utilizing a variety of weapons, such as small arms, missiles, mortars, and artillery. Therefore, prior to the consideration of gaps within the overall lethality capability area, one must first assess whether investment in development efforts will result in the right mix of systems to satisfy each of the specific fundamental capabilities. One such example is the small arms fundamental capability - the systems that provide this capability compose the small arms fundamental capability portfolio. The study of fundamental capabilities and their fundamental capability portfolios are the focus of this dissertation.

A portfolio can contain both 'major weapon systems' and less expensive systems. 'Major weapon systems' are estimated to require eventual research, development, test, and evaluation (RDT&E) expenditures of more than $300 million, or eventual procurement expenditures of over $1.8 billion. Major weapon systems have been the subject of extensive research in the past. However, since less-expensive systems make up 80% of the Army's acquisition budget, they should not be under-assessed. Indeed, in many cases less expensive, smaller systems will make up the majority or totality

of systems within a fundamental capability portfolio. Further, past research has focused on individual systems as standalone development projects and has not adequately considered the interdependency amongst systems in the overall development portfolio. Major weapon systems, due to their high cost, are often the only development effort aimed at filling a particular capability gap. On the other hand, amongst smaller systems there are often close substitutes or even directly competing systems - developed by a rival company or mandated by the Army itself– that could all fulfill a capability gap. As a result, in a portfolio management context, there is a question as to whether the development of closely related systems is wasteful redundancy on the one hand, or useful insurance against failure of some development programs on the other. The development paths of major weapon systems may also diverge from those of smaller systems. While major weapon systems are often developed to counter perceived future threats, which may give developers some scheduling leeway, smaller programs are often initiated to counter imminent, recently revealed threats, such as the use of novel IEDs by insurgents. For such systems, rapid development and fielding is of urgent importance given an environment in which casualties, rather than dollars, are often an influential driving factor in deciding whether to enter or continue an armed conflict or war.

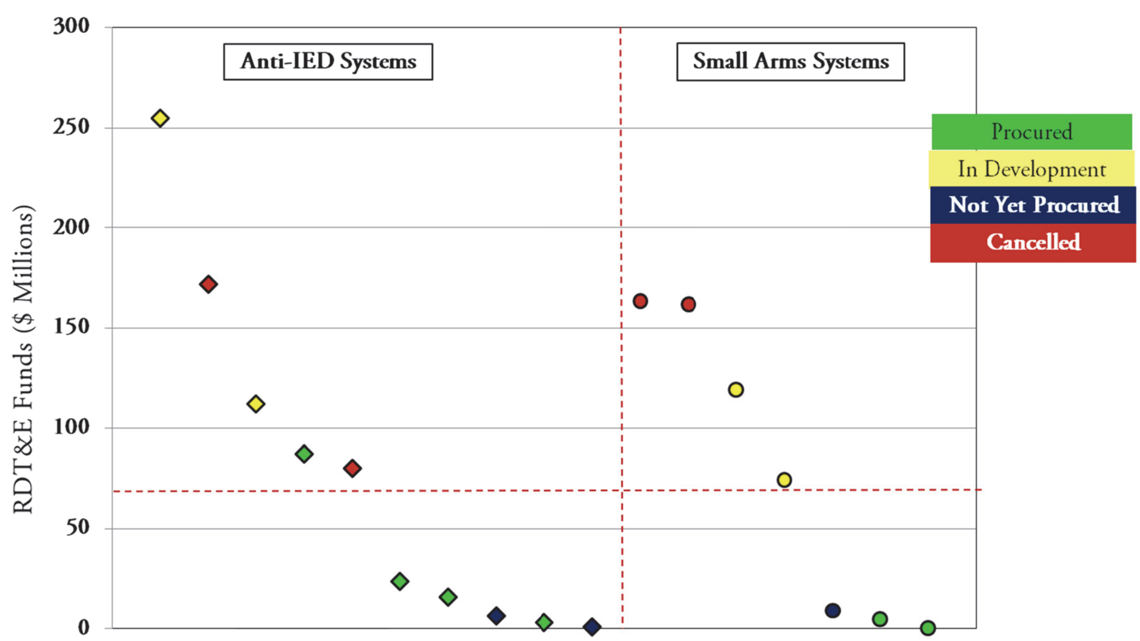
These observations motivate the performance of two 'fundamental' portfolio reviews within this dissertation that focus, respectively, on anti-improvised explosive device (anti-IED) systems and small arms. A fundamental capability portfolio review builds 'from the ground up' to assess how well the aggregations of individual under-development Army systems provide for each fundamental capability. Especially when the Army is under budgetary constraint, fundamental capability analysis allows for an understanding of complementarity and redundancy amongst developing systems so that one can select the most cost-effective portfolio of projects to fund. In turn, from individual fundamental capability portfolio reviews, one can aggregate findings and select projects that will most effectively satisfy a capability requirement area within budget. Aggregating at a higher level still amongst these capability requirement areas can result in an overall strategy for the total portfolio of developing Army systems.

The two fundamental capability portfolios reviewed herein were selected because of the importance of both groups of systems. Small arms contribute significantly to the lethality capability area, while anti-IED systems are, in the current anti-insurgency environment, a key aspect of the force protection capability area. The dissertation assesses seven small arms systems and ten anti-IED systems that were under development in fiscal year (FY) 2006, tracking each system from inception to current state, and analyzes how each system contributes to the respective fundamental capability area in question. The systems under study represent all of the small arms and anti-IED development programs that appear in the FY 2006 Army (RDT&E) records. RDT&E data, which tracks expenditures related to system development, are available for most systems from 1998 to expected future expenditures as far forward as 2015, resulting in seventeen years of available data. Systems under development in 2006 are at the midpoint between these two dates. Each portfolio review determines whether development projects and expenditure of development funds resulted in adequate fulfillment of capability gaps within the fundamental capability that applies.

A case study methodology was utilized to collect data related to development cost, development schedule, and expected capability provision of each of the systems under development. Each of the systems is considered in terms of its specific function within the fundamental capability portfolio, and in relationship to 'legacy systems' (if any), which are defined as already fielded systems that new, developing systems are meant to replace. Development outcomes of the systems indicate the overall success of the Army in meeting capability requirements during the chosen time frame.

In aggregate, the seventeen small arms and anti-IED systems that were analyzed can generally be split into two development cost levels. The vertical red dotted line in **Figure S.1**separates anti-IED systems on the left from small arms systems at the right of the plot. For both groups, the systems are ordered by most expensive system to least expensive in terms of total RDT&E funds, which are used to mature systems until they are ready to be manufactured and fielded. Nine relatively high-cost systems are above the horizontal red dotted line in **Figure S.1**, and all cost over $70 million, each. On the other hand, a group of eight relatively inexpensive systems lies below the red dotted line in the figure, and none cost over $25 million to develop.

Figure S.1 - Anti-IED and Small Arms Systems Costs and Outcomes



The more expensive group of systems tended to be novel systems, built from the ground up, and were relatively more ambitious in terms of providing new, unique capabilities. The less expensive group of systems were generally based on legacy systems, and more often than not were modifications of existing military systems, or commercial systems modified for military use.

Development outcomes suggest an inefficient use of research funds in terms of both the types of systems that were either canceled or never fielded as well as the dollar values associated with those systems. Over the course of the study period, four systems were terminated before development was complete, as indicated by the four red points in **Figure S.1**. All of these systems were from the relatively higher expense, more ambitious development group. In contrast, three systems largely completed development or were ready to be fielded, but have not yet been selected for procurement. All of these systems were from the less expensive group of development projects (blue points in **Figure S.1**). Six development projects resulted in procured systems that will be useful in the field (green points). Of these, only one was from the more expensive group of systems and was one of the least expensive systems to develop within that group. The other five procured systems result from lower-cost development efforts. The remaining four systems, still under development, belong to the group of higher development cost systems (yellow points).

On average, systems that are currently still in development have been in that state for just over twelve and a half years.

While four projects were canceled out of a total of seventeen, terminations represented nearly 45% of total development dollars accounted for in this study. If this finding among 17 systems is confirmed in future studies, the large percentage of funds lost to canceled program would be a serious concern, especially in the current (and indefinite) budget-constrained environment.

Cancelations and protracted development of systems often led to uneven coverage of capability gaps within fundamental capability portfolios.

The ten systems under development by the Army within the anti-IED fundamental capability portfolio fall into one of two categories: mine detection or mine neutralization. Development successes amongst mine neutralization systems have resulted in a dramatic decrease in the number of remotely detonated, wireless IEDs used against troops in Iraq and Afghanistan. In 2005, ninety percent of IED attacks in Iraq used remotely detonated, wireless IEDs. As of 2009, that number had dropped to twenty percent nationwide. A philosophy of quick-turnaround modification of preexisting military technology with rapid fielding across multiple development efforts was largely responsible for this victory. However, insurgents have adapted to new Army technology by shifting to the use of more primitive IEDs in Iraq and Afghanistan, which are impervious to electronic jamming, and which heighten the need for better mine detection systems as an alternative means of denial. Through the use of commercial systems and the modification of existing military technology, there have been successes in this area. However, the development of systems providing true standoff detection capabilities, that do not expose soldiers to the potential blast radius of IEDs, has been slow to develop or have been terminated.

Turning to the small arms fundamental capability portfolio, as of 2006 the Army had ambitious plans for technological transformation. A myriad of older systems were to be replaced largely by two revolutionary new weapons – the soldier-borne Objective Individual Combat Weapon (OICW) and the crew operated Advanced Crew Served Weapon (ACSW). These two systems, part of a group of seven small arms systems under development, were the cornerstones of the Army's long-term strategic vision. In the end, both systems were canceled. As a result, the portfolio of small arms weapons available to soldiers in the field now looks much the same as it did a decade ago, with few improvements.

Analysis of this sample of seventeen development projects leads to the following findings and recommendations:

Important findings:

Finding one: Less expensive systems are more likely to be successfully developed and fielded than more expensive ones. Within the context of the fundamental capability portfolio, more expensive systems also have the potential to fill larger capability gaps. In the anti-IED portfolio, the Airborne Standoff Mine Detection System (ASTAMIDS) and Ground Standoff Mine Detection System (GSTAMIDS) were two key systems in standoff mine and IED detection. Neither has been fielded to date. Within the small arms fundamental capability portfolio, the fielding of a new air-bursting smart munition promised by the Objective Individual Combat Weapon and Advanced Crew Served Weapon was extensively delayed as a result of the cancelation of both systems, resulting in the lack of an important capability for more than a decade.

Finding two: Technology is commonly salvaged from cancelled programs. Of the seventeen systems reviewed here, four were officially canceled. In each case, some portion of the technology was transferred to another development effort and in most cases resulted in fielding. Cancellation of development programs is therefore not synonymous with total failure.

Recommendations for individual systems:

Within a fundamental capability portfolio, the military should consider the value and urgency of need for a system before establishing multiple or overly ambitious initial requirements for a system, introducing new requirements following the beginning of development, or requiring integration between systems that are concurrently in some stage of development and not yet matured.

Recommendation one: Fielding useful and timely systems should be the goal of development. If development efforts with focused goals succeed in producing fielded systems, improved or new capabilities can be added once lessons-learned from real-world use are incorporated. This would get systems fielded to the troops in a timelier manner and provide a higher probability of success for system development. As an example, the Army fielded various iterations of IED jamming systems quickly to bring a vital capability to the field, without waiting for the systems to be at a perfected level of development.

Recommendation two: Realistic and simple initial requirements are highly desirable. The OICW and ACSW programs were required to be of lighter weight in comparison to legacy systems and at the same time had to fire both conventional ammunition as well as an air-bursting smart munition. In the case of the OICW, the integration of complex electronic components that calculated distance of explosion for the air-bursting munition would have inevitably added weight to the system and were thus directly contradictory to the requirement of weight reduction. As a result, the maturity of technology lagged behind Army guidelines at key development milestones. Given the need to fill capability gaps quickly, it might have made more sense to develop a light carbine for use by individual soldiers, while separately develop an air-bursting capable weapon to be deployed perhaps at the company level, as opposed to being issued to each individual soldier. This solution should be adequate, as an air-bursting capability is likely to be used relatively less frequently in combat than the traditional carbine.

Recommendation three: The use of commercial and government off-the-shelf technology (COTS and GOTS, respectively) – which has already been developed and can be modified for military use - should and currently is being emphasized as a potential source of capabilities, especially in a tight budgetary environment. The Ground Standoff Mine Detection System was characterized by demanding requirements such as avoidance from enemy detection and autonomous navigation that ultimately led to delay and cancellation. On the other hand, the Autonomous Mine Detection System (AMDS) utilizes technology originally developed for GSTAMIDS, which is to be integrated on a GOTS platform. While the capabilities of AMDS are lower than those of GSTAMIDS, development has taken much less time and is more likely to result in a fielded system.

Recommendation four: The Army should refrain from ‘requirement creep,’ wherein additional requirements are added to a system already undergoing development. The Airborne Standoff Mine Detection System was originally designed to provide standoff mine detection capabilities from the air, and was one of the few in-development systems that could fill that particular gap. However, during ongoing development, requirements were modified to also include enemy target (e.g. vehicle or personnel) acquisition requirements. These changes contributed to significant delays in the development of the system. ASTAMIDS was also developed concurrently with technologically immature UAV platforms that were meant to carry the mine detection system. However, concurrent development meant that some aspects of the final configurations of systems were unknown, complicating integration and increasing development cost. Worse yet, the intended host UAV systems was canceled and replaced by another still in development UAV on several successive occasions. As a result, integration efforts had to begin anew repeatedly, resulting in delay.

Recommendation five: In some of the cases studied here, new components with competing requirements were supposed to be integrated into a single system. However, program managers should balance the need for integration of new systems with the need to field capabilities in a timely manner. In the case of the OICW, several important components of the overall system were still in early stages of development even as integration of those components had to occur in order to remain on schedule. In particular, there were issues with the effectiveness of the blast provided by the 25mm air-bursting munition. If the shape or size of the round itself had to be changed, it would delay development of the main small arm system and potentially violate existing weight reduction requirements. On the other hand, if changes to the small arm could not have been made, it would mean requiring increased burst for the 25mm munition at a fixed size and weight. Technical issues such as these are likely to increase the risk of delay and cancelation.

Recommendations for portfolio management:

Recommendation one: Given the inevitability of failure in some development programs, effective portfolio management necessitates the explicit development of realistic alternative plans that initiate immediately in cases where no fielded systems seem likely to arise from current development efforts. In a tight budgetary environment, this may mean that development of an ambitious system is halted so as to fund systems providing a lower capability but a higher likelihood of near-term fielding.

Recommendation two: In choosing systems to develop, the Army should explicitly consider time to fielding and the risk of program failure of each system, and should attempt to fulfill capability gaps sooner rather than later. The cancellation of the OICW and ACSW in the small arms portfolio and ASTAMIDS and GSTAMIDS in the anti-IED portfolio left significant gaps in each fundamental capability portfolio. In considering higher-capability, higher-risk systems like these, the Army should not only assess the expected capability of the system, but should also consider the expected length of development of the system and likelihood that the development program will fail to meet performance or cost objectives. By engaging in these calculations, it may be that the Army opts to develop systems that provide fewer capabilities but are more likely to be developed quickly and successfully.

Recommendation three: Substitutes do exist between developing systems, but a safety margin is necessary in the fundamental capability portfolio to guard against inevitable challenges such as performance shortfall, schedule delay or cancelation of programs. As a result, policymakers should make careful considerations before cutting 'redundant' programs. In the small arms portfolio, the Lightweight Medium Machine Gun and M240L are similar machine guns developed relatively cheaply, at a cost to the military of $250,000 and $4.9 million, respectively. Bringing such systems to a 'ready to be fielded' state is inexpensive compared to the overall procurement, operating and maintenance budgets. Meanwhile, providing a safety margin in the overall portfolio is likely to be strategically important and economical, since it results in a higher likelihood of fulfilling a capability gap and/or lower procurement and operating and maintenance costs in the future if the most cost-effective system amongst a group can ultimately be selected for fielding.