

Strategy Research Project

Responsible Transition of New Materiel Requirements into Programs of Record

by

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United States Army War College
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Abstract

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The Department of Defense (DoD) and its services have unsuccessful in achieving effective acquisition reform for over 40 years. Programs, if they make it to production, continue to be late and over budget. Free market style competition, commercial off the shelf items, or modified acquisition techniques have also failed to produce better results. A system solution would require concessions from the Executive and Legislative branches of government, something the country is not likely to see due to natural tensions resident in the governmental system. However DoD has tools available to provide better acquisition outcomes. DoD must become more realistic in the capabilities desired and the technologies necessary to achieve them when transitioning into programs of record. Further, if revolutionary capability is desirable, DoD should be more realistic in the structuring of programs seeking "leap ahead" technology necessary to achieve these goals.

Responsible Transition of New Materiel Requirements into Programs of Record

We've tried to a better job in stating the requirements, keeping them less reliant on immature or unavailable technologies.

— Army Secretary John McHugh¹

The Department of Defense (DoD) and its services have actively engaged in acquisition reform for over 40 years. Despite these efforts, DoD's acquisition record remains tarnished in regards to Major Defense Acquisition Programs (MDAPs). Self imposed and legislative reforms heaped upon the DoD acquisition process have done little, if anything, to thwart the poor performance of MDAPs as a whole. Programs, if they make it to production, continue to be late and over budget. Panaceas such as use of free market style competition, commercial off the shelf items, or modified acquisition techniques have also failed to reform the system and produce better results. Reforming DoD's acquisition system is a true example of a complex and ill-defined problem, and one for which a solution that will eliminate all instances of poor performance is unlikely. A system solution would require concessions from the Executive and Legislative branches of government. This is something the country is not likely to see due to natural tensions resident in the governmental system. However there are tools available to DoD that can provide better acquisition outcomes than DoD currently experiences, and can be put to use immediately. In order to achieve the timely delivery of new or increased capability to the field, DoD must become more realistic in the capabilities desired and the technologies necessary to achieve them when transitioning into programs of record. Further, if revolutionary capability is desirable, DoD should be more realistic in the structuring of programs seeking "leap ahead" technology necessary to achieve these goals.

What is the Acquisition System

The Department of Defense lacked a formal acquisition policy before the 1960s because the Secretary of Defense either lacked the authority or chose not to enforce a policy.² This changed with the Department of Defense Reorganization Act of 1958, which, among other things, authorized the Secretary of Defense to assign weapons system procurement to any one of the services. This act, combined with the cost overruns of the 50s, set the stage for Robert McNamara's business management initiatives.

Secretary Robert McNamara came to the Pentagon as a senior leader in the Ford Motor Company. He desired to inculcate a business mentality in the DoD acquisition process. His initiatives in the 1960s represent the first attempt to establish an acquisition system common within DoD and provide centralized planning and decentralized execution by the services. He instituted the Planning Programming Budgeting and Execution (PPBES) that remains largely unchanged today. To provide greater oversight to contracts, the Department of Defense established the Defense Supply Agency (now Defense Logistics Agency), the Defense Contract Administration Service (now Defense Contract Management Agency), and the Defense Contract Audit Agency. To help manage programs DoD adopted the Program Manager concept whereby one person would have authority and responsibility for program execution. To support the program managers, DoD adopted a suite of management concepts to include Earned Value Management, Technical Performance Measures, Configuration Management, and Program Evaluation and Review Technique;³ all staples of programs today. These initiatives helped establish an acquisition framework across DoD.

This framework has since evolved into the Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System. This system is commonly referred to as the Big “A” and is famously represented by the chart in Figure 1. The chart itself often is a point of criticism and becomes a focal point for why DoD acquisitions suffer. While the chart is confusing, it is an attempt to capture all the tasks necessary to develop, produce, field, sustain, and retire a system with a potential lifecycle of over 50 years. This chart is usually the genesis for comment about the burdensome nature of the oversight directed onto traditionally developed military programs. Rather than argue about the complexity of the chart, it is more important to understand the three different functions represented on the chart.

The integrated system consists of three major processes. The first process is the Joint Capabilities Integration and Development System (JCIDS) responsible for developing and verifying the need for a materiel solution to meet a forecasted capability gap. The second is the Defense Acquisition System (DAS) responsible for developing, producing, and supporting the materiel item. The last function is the Planning, Programming, Budgeting, and Execution System (PPBES) responsible for managing the necessary funding for the materiel requirement. Combined the systems are commonly called the Big “A” acquisition process (Figure 2). While these systems must be integrated to work together to ultimately deliver capabilities to the force, they are controlled by different entities within DoD. Constant coordination is required between the stakeholders in the process. Like any system, when one process is out of balance, the other processes must adjust their inputs and outputs to bring the system back into balance.

Appendix A. The Acquisition, Technology, and Logistics System

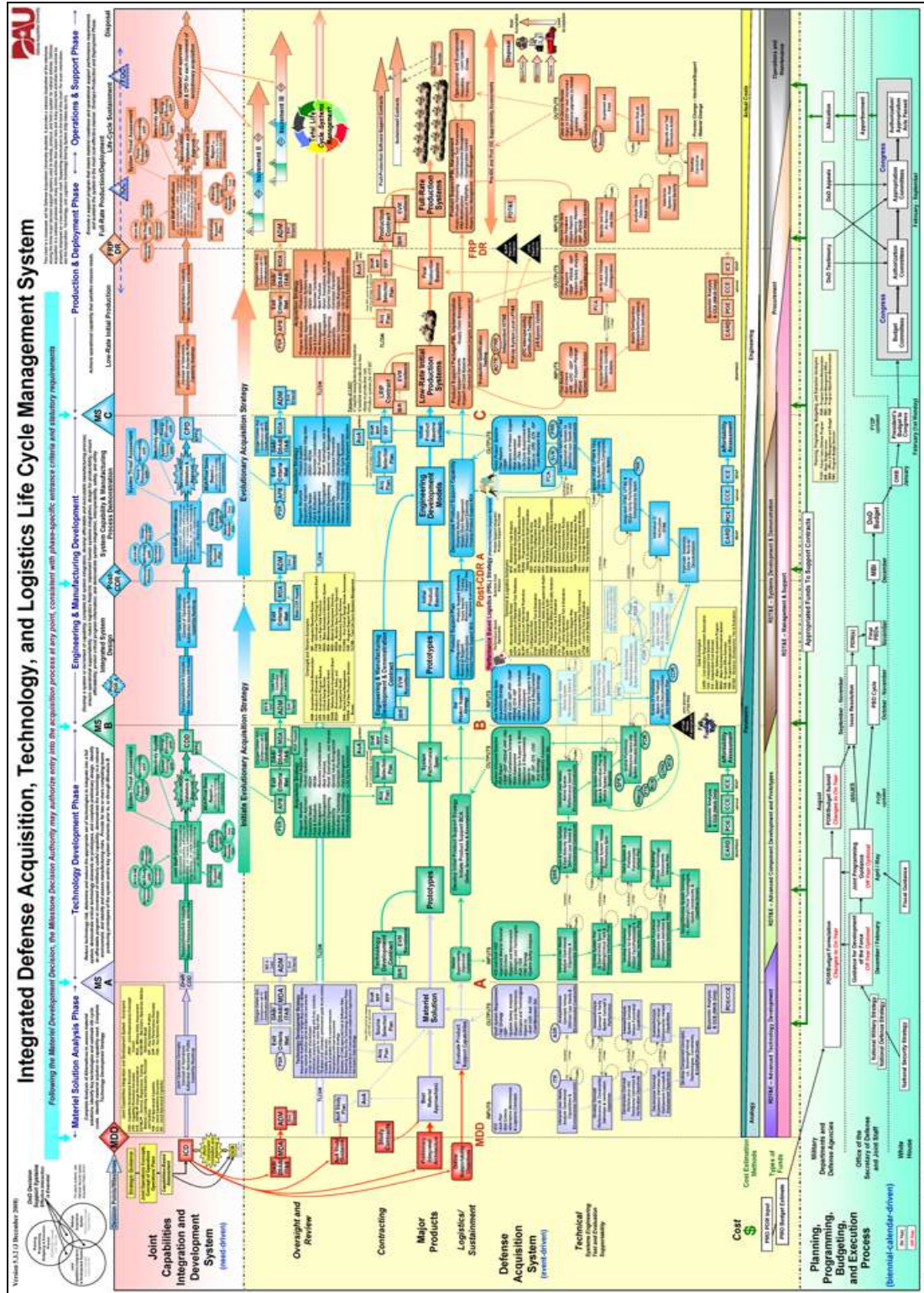


Figure 1. Acquisition, Technology, and Logistics System⁴

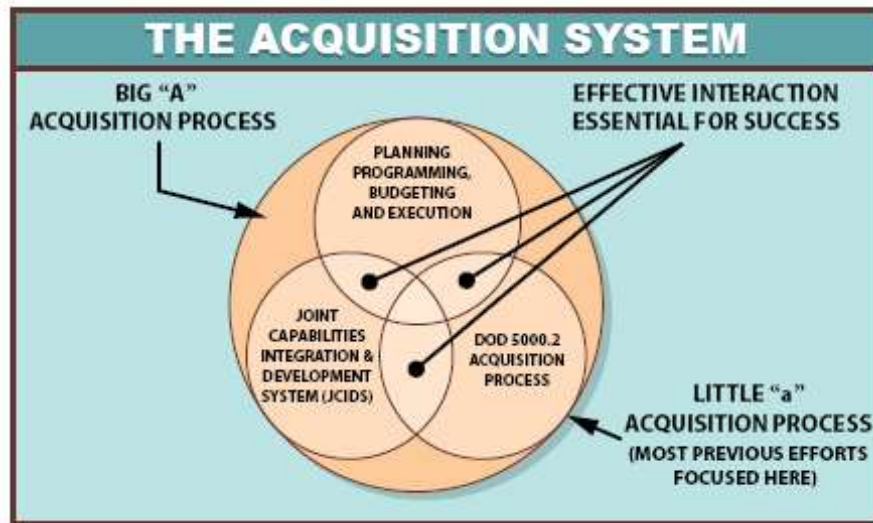


Figure 2. The Defense Acquisition System⁵

The foundation of the acquisition system rests upon the required capabilities and the definitions of those requirements through JCIDS. This process documents the requirement from the identified capability gap through development, production, fielding, support, and demilitarization. It serves as the base of any program and ultimately describes the desired capability in a performance-based manner. This process is under the control of the Joint Staff. Since the process establishes the capabilities DoD needs to meet future threats, it is generally less susceptible to outside influences. The ultimate arbiter of a new capability requirement is the Joint Requirements Oversight Council (JROC) consisting of the Vice Chairman of the Joint Chiefs and the Vice Chairmen of the individual services. Assuming that a requirement is not urgent, this process may take up to two years. Even after two years of work, a program may not become a program of record until it is fully funded.

Concurrent with the development of the requirement is the PPBES function of the acquisition system. This process identifies and manages the funding of a program over its lifecycle. In order for a program to proceed it must be fully funded to the accepted

estimate submitted by the sponsor. Unless the sponsor requests reprogramming of current year funds, the program will generally wait until the next budget year for funding. Further, the requirement that the funds for a new start program remain within the topline DoD budget and forces the Services to balance a new materiel requirement against its portfolio of ongoing materiel requirements. This process may take up to two years as well.

Once a requirement is approved and fully funded, it is transitioned to the DAS and a Program Manager to take an identified capability gap and develop a materiel solution. This process has four distinct phases: 1) Materiel Solution Analysis, 2) Technology Development, 3) Engineering and Manufacturing Development (EMD), and 4) Production, Deployment and Support. Between each phase is a milestone review conducted by OSD or the Service depending on the level of oversight. These milestone reviews determine if the goals of the phase were met and if the program is ready to proceed into the next phase. The milestones between each phase are identified A, B, and C, respectively. The JCIDS and PPBES processes of the framework continue to play a role in a program, especially at each milestone, to ensure the overall requirement is still valid and available funding is adequate.

The start of EMD, following a Milestone B Review, is when a program baselines its performance, cost, and schedule requirements and becomes a program of record. This baseline serves as the measuring point for a program's progress until it completes production. Thresholds established by Congress (commonly referred to as Nunn-McCurdy thresholds) provide trigger points whereby DoD must conduct a review of the capability requirement and determine whether it is still necessary to meet national

security needs. It is also at Milestone B that the maturity level of the technology necessary to meet the capability requirement becomes critical. Transitioning immature technology into a program of record without providing additional resources adds significant performance, cost, and schedule risks to a program.

Acquisition Strategy and Risk

Combined, the application of JCIDS, DAS, and PPBES form the acquisition strategy for developing, fielding, and sustaining a materiel solution to meet a desired capability. The acquisition framework in Figure 1 can be confusing for those who are not acquisition professionals. By defining the framework within the Army War College's doctrinal definition of strategy, it becomes easier for strategic leaders to understand to the framework. JCIDS represents the ends, the DAS represents the ways, and PPBES represents the means. Visualization of this strategy is pictorially represented by Art Lykke's three-legged stool. For the strategy to be successful the legs must all be in balance, lest the chair topple over. If one of the legs is out of balance, there is risk in the system. Risks can reside in any or all of the legs of the stool. Once identified, the risk must be controlled, avoided, accepted, or transferred⁶ for the system to remain in balance.

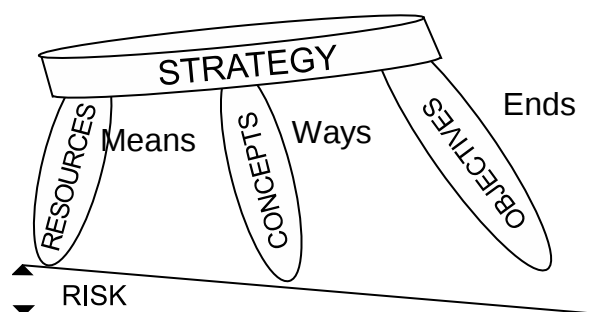


Figure 3. Art Lykke's Depiction of Risk⁷

The acquisition framework is an open-system and subject to forces outside JCIDS, DAS, and PPBES. Congress, the threat, the US population, lobbyists, and defense industry companies all may have input to the system: directly or indirectly. Just as the system responds to internal instability it must also react to external instability. This external instability may be a change in the perceived enemy threat and thus a change in the requirement for the materiel solution, increased oversight requirements, or adjustments to funding levels. Regardless, the system must balance its ends, ways, and means or accept additional risk and prepare to adjust should the risk be realized.

Achieving a balance of ends, ways, and means is difficult. The main parties involved in achieving the balance (DoD, Congress, Defense Industry) all desire successful outcomes but their definitions of success do not necessarily align. There are natural tensions and egocentric desires involved. Congress desires the achievement of the goal while meeting strict oversight requirements and other public policies such as small business contracting goals. The Services desire to start more programs than they can afford otherwise⁸ and are willing to accept risk and success based, high-risk estimates. The defense industry companies desire the achievement of the goal, but in a way that maximizes shareholder value. In doing so, they are not willing to take on additional risk without increased compensation. Further, they are able to capitalize on the additional work caused by program restructures and support to additional oversight that are a result of the tensions between Congress and DoD.

State of the Acquisition System

The Department of Defense Acquisition Process has been under perpetual scrutiny since the end of World War Two. In 2003, then Secretary of Defense Donald Rumsfeld identified 128 studies of the Defense procurement system since 1975 alone.⁹

These included studies from DoD, Congress, the Government Accountability Office (GAO), and think tanks such as the Research and Development (RAND) Corporation. The main intent of these studies was to identify and recommend solutions to the root causes of the cost growth and schedule delays of DoD's MDAPs. The budget impacts of these program increases continue to be significant. The most recent GAO review of ninety-six active 2011 MDAPS indicated a total cost increase of \$447 billion over the life of the programs, and an associated average delay of 23 months.¹⁰

While MDAP overruns and delays continue to be significant, cancellations also factor into the justification for reviews of the acquisition process. The Army alone has invested over \$32 billion since 1995 in development of capabilities that never transitioned to production because the programs were cancelled.¹¹ While this total may not seem like much when compared to DoD overruns as a whole, it represents almost 40 percent of the Army's research and development dollars over the same time period.¹² The Future Combat System represents the majority of the Army's cancellation loss at roughly \$19 billion.¹³ The Comanche Reconnaissance Attack Helicopter accounts for another \$5.9 billion after 22 years of development.¹⁴ The Army's final big-ticket item is the Crusader artillery system at \$2.8 billion invested.¹⁵ All, three of these programs failed to demonstrate mature technologies before transitioning into EMD and establishing a program of record.

The Army is not alone in its troubles in acquiring new capabilities. The Navy's cancellation of the A-12 stealth fighter was a \$2.68 billion loss¹⁶ and resulted in a court case between the US Government and Boeing that lasted for over 20 years. The Navy terminated the VH-71 Presidential Helicopter replacement program when it fell six years

behind schedule and doubled in price. The cancelation loss was \$3 billion in sunk costs¹⁷ and President Obama remarked that it “was an example of a procurement process gone amuck.”¹⁸ The Air Force’s F-22 ballooned in cost from \$139 million per plane to \$412 million per plane resulting in a reduced procurement from 750 to 187 aircraft.¹⁹ Jointly, DoD has not fared much better as the cost of the F-35 Joint Strike Fighter has increased 78% from \$74.6 million to \$132.9 million per copy.²⁰ The Defense Acquisition Executive, Frank Kendall, called the program an example of “acquisition malpractice.”²¹ Again, all of these programs failed to demonstrate the mature technologies necessary to meet the performance requirements before entering EMD.

While the aforementioned examples are relatively recent, they are demonstrative of a problem that has plagued the Department of Defense since the end of World War Two. Following the war, budgets and new systems development dropped significantly as the nation took a “peace dividend.” The dividend stopped paying in 1950 as America began arming for the Cold War, and by the end of the Fifties the services placed the greatest emphasis on systems containing the most advanced technological innovations.²² Along with greater emphasis on technology came significant cost overruns as the departments developed and produced systems under cost reimbursable contracts. These types of contracts limit the amount of profit a company may earn but they do allow a company to recoup all costs associated with the program regardless of a company’s performance. Effectively the Government assumed the risks of development and production and these cost overruns provided the genesis for the first acquisition reform initiatives designed to codify DoD’s acquisition system.

Acquisition Reforms and Lack of Progress

McNamara's initiatives in the 1960's laid the groundwork for what has become DoD's current acquisition system. He believed that establishing a system with centralized oversight and decentralized execution would eliminate the poor performance previously experience. Despite his initiatives, costs and schedules of MDAPs continued to exceed their initial estimates. A GAO review of 38 MDAPs in 1970 indicated cost increases 50% higher than their original contract figures.²³

In light of the perceived inadequacy of the acquisition system to this point, the legislative and executive branches initiated a series of acquisition reforms that continue regularly to this day. These reforms generally seek the same outcome: delivery of capabilities on time, on budget, and meeting the desired requirements. The sheer volume of reform efforts is significant as indicted earlier. Though overwhelming, it is possible to identify a handful of significant reforms since the 1970s that identify common trends. The Fitzhugh Commission (Executive Branch-1972), the Congressional Commission on Government Procurement (Legislative Branch-1972), The Packard Commission (Executive Branch-1986), DoD Advisory Panel on Streamlining and Codifying Acquisition Laws (Legislative Branch-1993), and the Defense Acquisition Performance Assessment (Executive Branch-2006) represent the most senior level reviews that also resulted in reforms to the acquisition system.

These reforms usually evolve from a failure of the acquisition system. These failures manifest themselves as significant cost and schedule overruns, or cancellation of a major program due to the unlikelihood of the program achieving its performance objectives. Generally speaking, the reviews and subsequent reform efforts focus on the DAS part of the framework and give only cursory treatment to JCIDS and PPBES as

sown in Figure 2.²⁴ These reforms resulted in greater oversight by entities both within and outside DoD. While not all inclusive, many of the major reviews have common themes of holding program managers accountable, decentralizing execution of programs to the program manager, using commercially available items, implementing competition based on a free market model, and emphasizing realistic testing before EMD or production approval. Not surprisingly, reviews sponsored by the executive branch tend to emphasize less oversight as the solution and those sponsored by the legislative branch tend to emphasize the need for greater oversight.

This dichotomy demonstrates the natural tension in the acquisition system: checks and balances between the two branches. This tension often plays out on the political stage preceding or following a reform action. DoD acquisition members point to burdensome oversight as the cause of acquisition failures. Congress paints a picture of irresponsible DoD members as the cause, and therefore the need more oversight. Reality is that neither belief is true. There are extreme examples to each argument but they are the exception rather than the norm.

Across the enterprise neither opinion is a root cause for a system development failure. DoD asserts that Congressionally directed instability, mainly in funding, causes program failures.²⁵ Congress, through the GAO, asserts and demonstrates that successful programs maintain stable funding. Funding stability itself does not guarantee a successful program.²⁶ The same can be said of “excessive oversight” alleged by DoD. The oversight itself does not cause a program to fail. It may uncover problems but in the end excessive costs and the inability to meet requirements cause programs to fail.

This does not mean the oversight directed by both Congress and other agencies is without a corresponding burden. This burden is the focal point of both sides' arguments yet it appears to be a problem the Government as a whole is willing to live with, and it is delivering exactly what each customer desires.²⁷ There is an internal set of conflicting priorities designed into the system. The Department of Defense desires to maximize efficiencies, which requires decentralized decision making and which requires control of the ends, ways, and means. Congress desires to minimize the chance of a mistake, which requires tight control of funding and intensive oversight of the processes.²⁸ In the case of the current system the latter wins.²⁹ The envisioned checks and balances directed by our Constitution actually result in added turmoil and instability³⁰ as the two arms of the government wrestle for power. Kenneth Krieg, former USD (AT&L) commented on this conflict as, "[DoD is] the only enterprise in the world that would spend millions to prevent the fraud of pennies."³¹

The GAO Review "Weapons Acquisition: A Rare Opportunity for Lasting Change" (Legislative Branch-1992) is one review worth noting independently as it tried to identify root causes that have prevented other reforms from taking hold and producing better outcomes. This report analyzes a need to address the underlying acquisition culture that exists throughout both DoD and Congress.³² The natural tension between DoD and Congress creates a culture of undue optimism and a willingness to accept more risk than is prudent. This manifests itself as the Services, operating under finite budgets, make decisions of reducing support for one program in favor of funding a new one. In an attempt to keep both, a Service may accept and promote a low probability, success based schedule and budget, not accounting for concurrency (a strategy that combines

or overlaps phases of a program such as continuing EMD while starting production)³³ or technical risks. The contractor supports this system by providing proposals that will fall within the expected budgets necessary to keep the program alive. Similarly, these proposals are success based and substantiated with paper studies, which are not necessarily hard evidence of the technology's true level of maturity and increase risk. Congress supports this system with its two different roles. One role provides oversight and controls the budget while the other provides its constituency with the local jobs created by these programs. Other entities play into this system as shown in Figure 4. In the prevailing interest of compromise, leaders try to find a way to afford all programs rather than decide whether or not the materiel solution to the requirement should be sought at all.³⁴ The review concludes that a program's instability is the result of problems incorporated through this culture and that the instability is the price paid for the program to survive at all.

It is unlikely that this culture will change. Basic doctrine in change management indicates it takes 5-10 years of continual effort to really affect and direct a culture to a new norm.³⁵ Stability within the system is not sufficient to support sustained change. There have been 18 Secretaries of Defense in the 43 years since McNamara, Service senior leaders change every two to four years, Congressional elections are every two years, and presidential elections every four years. These continual leadership changes negate the stability necessary to make effective change. Also, the tensions in the system between DoD and Congress prevent an opportunity for change, and the system continues producing results that both parties are willing to live with rather than give up their power.³⁶

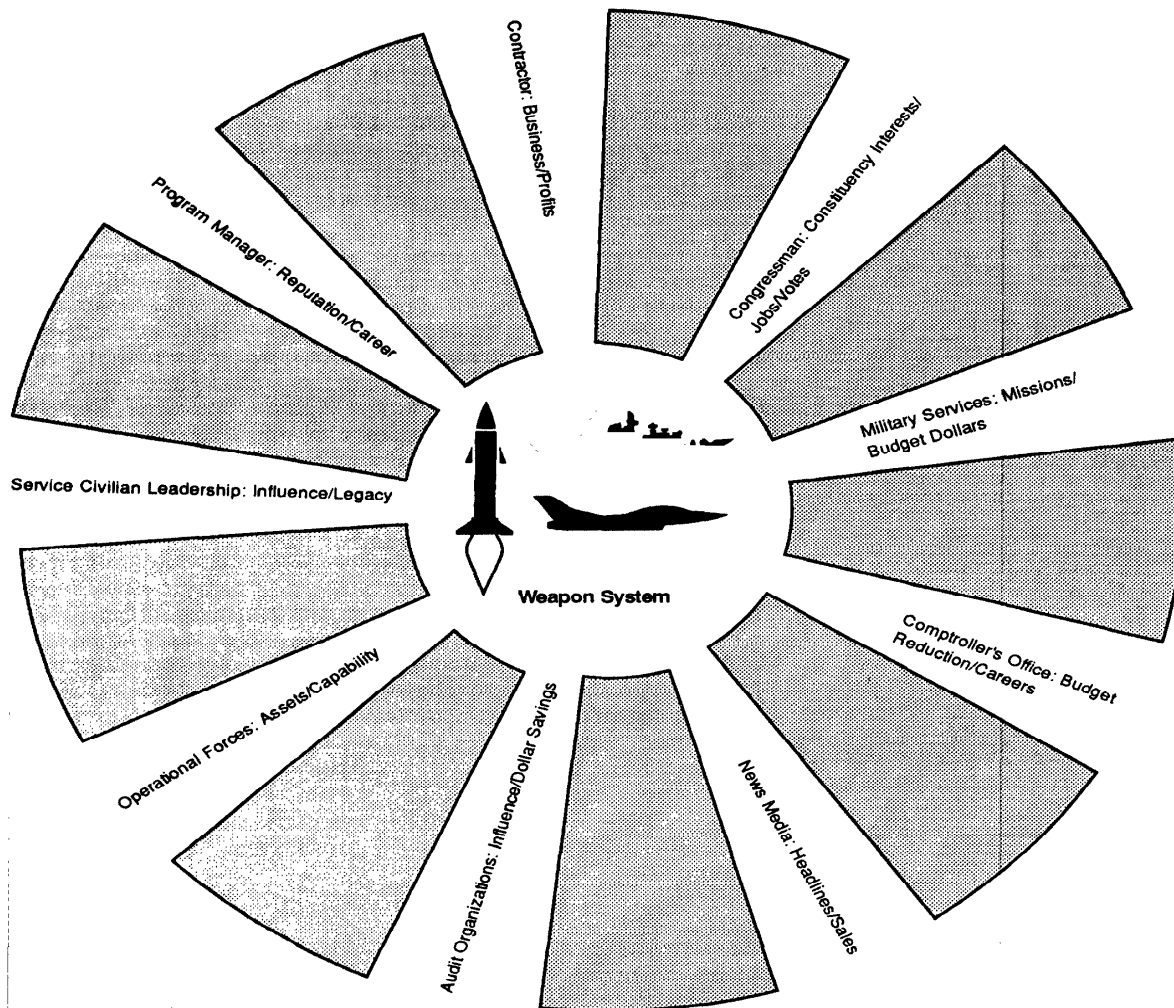


Figure 4. Diverse Needs of the Defense Acquisition System³⁷

Regardless of the themes, biases, or identified root causes within the reviews and subsequent reforms, DoD has not seen a performance improvement in developing and fielding MDAPs. In 1993, RAND performed a study of 197 programs with start dates between 1960 and 1990 to determine if acquisition reform since the Packard Commission made programs more successful. Unfortunately, the report found no statistical improvement in program performance during this period. The average program cost growth was around twenty percent throughout the entire period.³⁸ This trend has not improved with time or subsequent reforms as noted in the 2012 GAO

review of the current ninety-six MDAP programs with a forty percent average cost increase across DoD portfolio.³⁹

No Simple Solution to a Complex Problem

Just as the intensive reviews and subsequent reforms have not solved the problems facing the acquisition system, neither will simple solutions applied across all acquisitions. The first of these solutions proffered by the governmental branches, industry, and think tanks tend to focus on a belief that DoD acquisitions can operate just as a commercial business in a free market economy. Another frequently cited theory points to “successful” programs such as Mine Resistant Ambush Protected (MRAP) vehicle’s use of a “modified” acquisition procedure to cut through bureaucracy. These offer solutions to help improve the system in a limited way but do not provide a framework to guarantee success for all acquisitions.

There is little doubt in the ability of the free market to manage product development for a business. Quite simply, if the business does not meet the market’s need, the business will fail. However, a free market system has several critical differences from DoD and its acquisition system. At the most basic level a marketplace system pits competitors against each other for large numbers of customers. The market system controls profits by how much the consumer values the product, and the desire to cut costs is driven by the ability to make greater profits.

Defense acquisition pits a small number of competitors against each other for the business of one customer: DoD.⁴⁰ In this framework profits are tightly controlled and audited by the Government. Regardless of the value of a new weapon, the government will try to limit the profit built into the price. There is little incentive to cut costs, as these cuts will not lead to equally greater profits. To further exacerbate this situation the

demand from the one customer is highly unpredictable and susceptible to the previously discussed outside influences impacting the ends, ways and means of the acquisition system. Subsequently, additional risk is added.

Even if these differences did not exist, there is no guarantee marketplace mechanisms will help in the successful development and fielding of a complex item. The Boeing 787 presents a relevant example. Conceived in the early 2000s as a revolutionary approach to commercial airplanes, the 787 incorporated the latest in composite lightweight materials and engine development. The goal was to reduce fuel usage by twenty percent while maintaining the same speeds of previous generations of aircraft.⁴¹ The program began in 2004 with an original development estimate of \$5.8 billion⁴² and first deliveries expected in 2008⁴³. The final development cost is estimated to be about \$15 billion⁴⁴, an increase of 258%, and first delivery was over three years late as of September 2011.⁴⁵ This increase only represents the cost overruns associated with the initial development. Boeing is also expected to lose \$4 billion per year until they can reduce their production costs and actually make money on each plane completed.⁴⁶ Conservatively, Boeing will have to deliver about 1,900 planes before the company recoups its development and production investments.⁴⁷ To make matters worse, the Federal Aviation Administration and other international aviation safety agencies grounded the Boeing 787 fleet in January 2013 for safety concerns.⁴⁸ Deliveries will be further delayed until the identification root causes and implementation of corrective actions.⁴⁹ Despite having the ends, ways, and means in balance, the marketplace did not guarantee the successful development and fielding of a complex product.

Another common belief is that reducing the complexity of the acquisition system will result in better outcomes. Examples of successful programs using a model like this include the MRAP, the Army's Rapid Equipping Force, and Special Operations Command's acquisition system. Each of these acquisition models possesses a common tenet. This tenet focuses on achieving a capability through what is commercially available or through mature technology that can be rapidly integrated and demonstrated in a realistic operating environment. If the technology or commercial item cannot meet the full requirement, the requirement is generally lowered if the capability provided is greater than what is currently in the field. Future iterations would provide incremental improvements, if possible, with a goal of eventually meeting the full requirement. All of these examples, while successful for what they do, are not acceptable for all procurements unless the basic tenet, mature technology, is met. Failing to meet this and forcing a capability requirement with immature technology through an MRAP type model is very likely to lead to an unfavorable outcome.

While willing to adapt the ends of the program as necessary, the MRAP was able to modify the means and ways of the program as well. Secretary of Defense Robert Gates was dissatisfied with the seemingly slow process of deploying a capability to Iraq to counter deadly Improvised Explosive Devices (IEDs). He declared the MRAP as DoD's number one program in May 2007. Working closely with Congress and acquisition officials, DoD delivered 10,000 vehicles (of 24,000+ required) a little over a year later.⁵⁰ Funding for the program was done through a supplemental appropriation from Congress that provided the funds above DoD's total authorization. This high level

support and attention shortened the traditional two plus-year cycle to fund a new program.

The technology to meet the requirement was mature and largely proven in the fielding of other programs. The Army and Marine Corps were operating a limited number of RG-31 and other mine clearing vehicles in Iraq and seeing tremendous results in regards to crew protection. This head start enabled leveraging of survivability and other operational testing to ensure the product was suitable, effective, and safe for our troops thus reducing the time to deploy the capability to the field. The remarkable feat of contracting, manufacturing, and delivering this many vehicles, this quickly is a remarkable event for an acquisition system frequently called “antiquated.”⁵¹

This process worked well because the most senior DoD leaders and Congress championed and aligned the ends, ways, and means. However, to expect this type of cooperation for all MDAPs would be unrealistic. The means part of the strategy worked primarily because Congress was willing to appropriate funds quickly and above the Department’s top line. This eliminated the delays caused by the services deciding what needed to be cut from the budget to fund a non-standard solution. The ways aligned because the technology was mature and performance capabilities were operationally demonstrated with the RG-31, significantly reducing risk. These last two are important as the program incurred a significant concurrency risk with thousands of vehicles on production orders before adequate operational testing was complete.⁵² While concurrency usually increases risk, balancing this risk with mature technology significantly reduced the overall risk.

However successful the MRAP procurement was, it does not serve as a model for use with all acquisitions, especially those requiring exquisite technology. The prevalent conditions of the program represent a unique experience, one that is not likely possible to recreate without the presence of a clear danger such as that with the IEDs. The unique display of bipartisanship between DoD and Congress in balancing the means contravene the natural tensions between the executive and legislative branches. The ways used, especially the use of concurrency, are too risky for a normal developmental program as the counter balance of mature technology is generally not available.⁵³ Failing to meet these basic tenets of the MRAP program, and aligning the ends, ways, and means will significantly increase risk of any program that uses a modified acquisition process.

Recommendations

As demonstrated, changing outcomes within the Defense Acquisition framework is a daunting task. It is doubtful leaders can enact the overarching changes necessary to reform the entire system. The tensions, embedded by the Constitution and further enflamed by partisan politics and governmental branch battles, make it unlikely. That does not mean DoD should sit idly.

The PPBES and DAS aspects of the framework are very susceptible to outside influences from Congress and other entities. These influences inject instability into the system as a whole and force the other areas to adjust to keep the ends, ways, and means in balance. The JCIDS process though is less susceptible to influence as the JROC must approve changes to a program's requirement and the process is controlled by the Joint Staff. This stability offers the best place for DoD to control programs by managing the requirement and matching realistic requirements with demonstrated

technology before entering EMD. This greatly decreases risks, helps keep ends, ways, and means in balance, and reduces instability from the other processes.

Matching the available technology to a requirement at the onset of a program at Milestone B is the most critical step in establishing a program on the path to success as depicted in Figure 5. This was the foundation that made the MRAP program so successful in terms of rapidly delivering an increased capability. Future DoD programs can do the same by matching the requirement to the technology available.

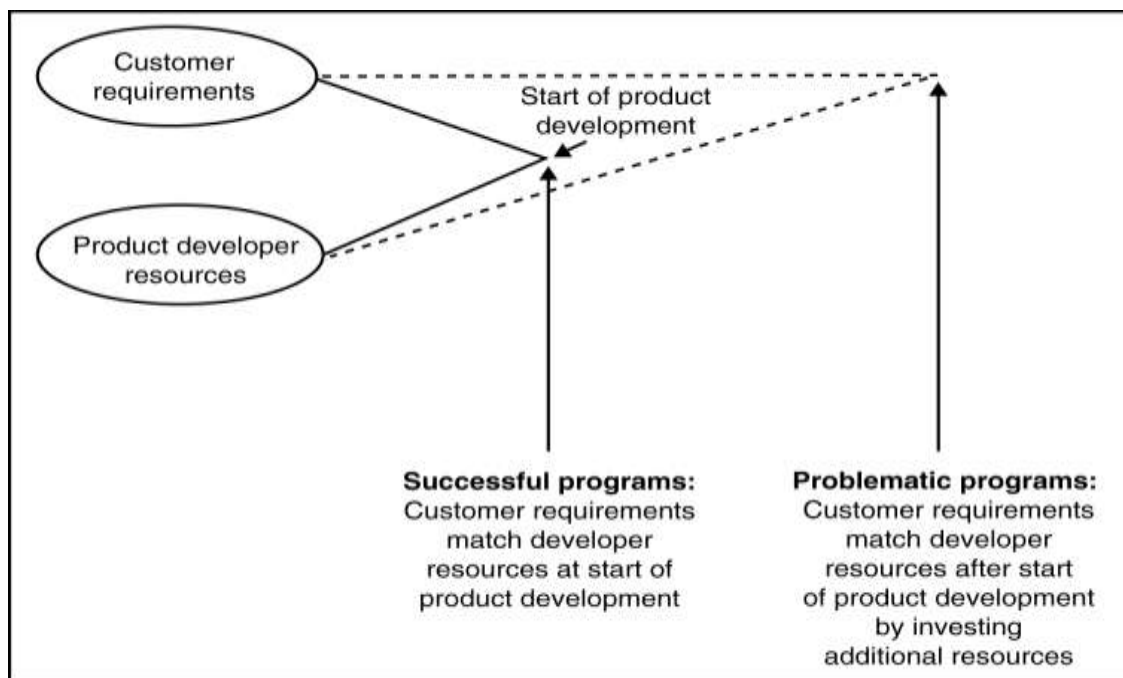


Figure 5. Matching Requirement to Technology⁵⁴

Failing to match a capability requirement to the technology reasonably available increases the concurrency risk to the program. Just as concurrency creates a risk when the EMD and Production phases overlap, it also creates risk when Technology Development and EMD phases overlap. The later in the design cycle technology development continues, the greater the consequence of a realized risk becomes. Redesigning a technology will frequently bring the rest of EMD to halt in order to

complete the technology development and then will require significant rework and retesting to incorporate the new solution.⁵⁵ Many times, this risk is either present when a program transitions through Milestone B, or is introduced after Milestone B through a change in requirements or demands for an accelerated schedule. The last two of these risk influencers is completely controllable in the requirements process. This does not mean that the answer should be “no” every time an additional requirement or schedule acceleration is needed. Rather, the Services must go back to the ends, ways, and means and make adjustments to bring them back in balance, preferably without introducing or increasing concurrency. Failure to do so only compounds the risks.

The Technology Readiness Level (TRL) (Figure 6) is a tool used to measure technology maturity from concept to operational use. While useful, it is a tool that is not uniformly applied in evaluation of programs moving forward into EMD⁵⁶ and can result in resident technology risks as a program proceeds past Milestone B. By law, a technology should be at a TRL 6 in order to progress through Milestone B.⁵⁷ The systems engineering directors of DoD and the Services are the proponents for this concept and responsible for monitoring performance and ensuring truth in reporting. Program decision makers must be willing to make the hard decision to hold a program from progressing when technology is not yet mature and poses down stream, concurrent risk. Consistent application and understanding of technology maturity would provide DoD programs a greater understanding of the risk and thus allow the matching of the available technology to the requirement. If a program must proceed without matching the requirement to the technology an adjustment to the ends, ways, and means is required.

Technology Readiness Level	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Figure 6. Technology Readiness Levels⁵⁸

MDAP program managers should not only consider technology maturity, but also the integration maturity of the components and sub-systems. MDAPs generally seek complex systems or system of systems solutions. This brings in a new level of scrutiny necessary to ensure the different technologies, even if mature, will work together to produce an effective system. A relatively new concept is the Integration Readiness Level (IRL). Similar to TRL in construct, the IRL attempts to demonstrate a maturity level of the different technologies performance when integrated together (Figure 7).

DoD

	IRL	DEFINITION	DESCRIPTION
PRAGMATIC	9	Integration is Mission Proven through successful mission operations.	IRL 9 represents the integrated technologies being used in the system environment successfully. In order for a technology to move to IRL 9 it must first be integrated into the system, and then proven in the relevant environment, so attempting to move to IRL 9 also implies maturing the component technology to IRL 9.
	8	Actual integration completed and Mission Qualified through test and demonstration, in the system environment.	IRL 8 represents not only the integration meeting requirements, but also a system-level demonstration in the relevant environment. This will reveal any unknown bugs/defect that could not be discovered until the interaction of the two integrating technologies was observed in the system environment.
SYNTACTIC	7	The integration of technologies has been Verified and Validated with sufficient detail to be actionable.	IRL 7 represents a significant step beyond IRL 6; the integration has to work from a technical perspective, but also from a requirements perspective. IRL 7 represents the integration meeting requirements such as performance, throughput, and reliability.
	6	The integrating technologies can Accept, Translate, and Structure Information for its intended application.	IRL 6 is the highest technical level to be achieved, it includes the ability to not only control integration, but specify what information to exchange, unit labels to specify what the information is, and the ability to translate from a foreign data structure to a local one.
	5	There is sufficient Control between technologies necessary to establish, manage, and terminate the integration.	IRL 5 simply denotes the ability of one or more of the integrating technologies to control the integration itself; this includes establishing, maintaining, and terminating.
	4	There is sufficient detail in the Quality and Assurance of the integration between technologies.	Many technology integration failures never progress past IRL 3, due to the assumption that if two technologies can exchange information successfully, then they are fully integrated. IRL 4 goes beyond simple data exchange and requires that the data sent is the data received and there exists a mechanism for checking it.
SEMANTIC	3	There is Compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact.	IRL 3 represents the minimum required level to provide successful integration. This means that the two technologies are able to not only influence each other, but also communicate interpretable data. IRL 3 represents the first tangible step in the maturity process.
	2	There is some level of specificity to characterize the Interaction (i.e. ability to influence) between technologies through their interface.	Once a medium has been defined, a “signaling” method must be selected such that two integrating technologies are able to influence each other over that medium. Since IRL 2 represents the ability of two technologies to influence each other over a given medium, this represents integration proof-of-concept.
	1	An Interface between technologies has been identified with sufficient detail to allow characterization of the relationship.	This is the lowest level of integration readiness and describes the selection of a medium for integration.

Figure 7. Example of Proposed IRLs⁵⁹

Directive 5000.1 directs program managers to reduce integration risk prior to the design readiness review,⁶⁰ but DoD has not yet incorporated IRLs into its processes.

The Decker Wagner Report to the US Army recommended development of the concept and incorporation into Army processes.⁶¹ Surprisingly, the Army rejected this recommendation citing that the other reviews currently required are sufficient.⁶² DoD should incorporate IRL requirements for continuation into EMD and production to provide a common framework for discussing integration risk and risk reduction going forward.

In addition to the use of TRLs and IRLs to ensure technology maturity, programs should rely less on paper studies of a technology's capabilities and rely more on realistic testing of prototypes.⁶³ Realistic testing of systems and sub-systems in operational environments will significantly lower the future risk of a program.⁶⁴ Further, DoD must measure the test results against the program's requirements. If the program does not meet the requirement, DoD should either adjust the requirement or continue technology development until the system can meet it.

A test vehicle's level of maturity can significantly increase or decrease the risk. Figure 8 demonstrates the spectrum of maturity in test vehicles from a proof of concept demonstrator to a full production prototype. Frequent acquisition reform reviews examined the success of the F-16 in development.⁶⁵ The genesis of its success relates back to the initial development of the YF-16 and the demonstration of its capabilities using a prototype aircraft before entering EMD. By the time the prototype YF-16 went through testing, the contractor had learned most of what there was to know about producing the aircraft.⁶⁶ Conversely, The JSF entered EMD with only a proof of concept demonstrator, one that failed to use the key technologies necessary for success.⁶⁷ In fact, none of its eight critical technologies were mature, much less demonstrated.⁶⁸ DoD

should require programs to demonstrate maturity with system prototypes that present the least risk as demonstrated in the scale below.

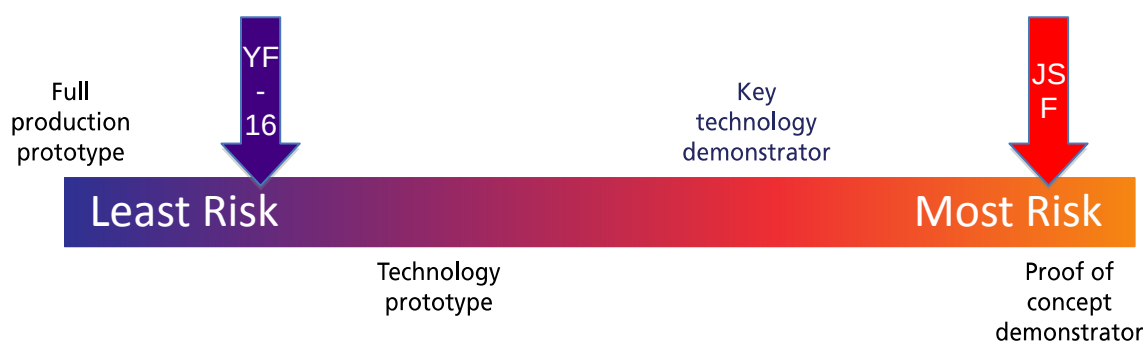


Figure 8. Scale of Prototype to Demonstrator⁶⁹

This failure to adequately demonstrate critical technologies has a ripple effect on a program's cost estimates. A key example was the inability of the engine to generate enough thrust for all variants of the JSF by the demonstrator's F-119 engine. The F-135 engine solved the thrust problem, but its larger size required a redesign of the airframe. In turn, this redesign changed everything from aerodynamics to the stealth signature of the aircraft, necessitating a rebaseline of performance measures.⁷⁰ These changes then rippled through both the developmental and production costs of the aircraft, increasing both. Failing to provide demonstration of key technologies prior to EMD has hampered the JSF program since its inception.⁷¹

Conclusion

At the macro level there is no denying that the equipment provided to the fighting men and women of the United States is the best, most capable, and most advanced in the world. Despite this, DoD's acquisition process has been under continual scrutiny since the end of World War Two. The hundreds of reviews and the implementation of legislative changes have done little to improve DoD's ability to produce MDAPs on time,

on budget, to meet the performance requirements. It is unlikely given the tension of the system that this goal will ever be reached. The sacrifices necessary from all stakeholders internal and external to the system are too great.

The promises of a solution based on one success story are fleeting, as the basis for that success is a very narrow set of circumstances within a specific framework. Failing to match the exact circumstances and attempts to accommodate an exquisite requirement into the framework leads to failure. There are no simple solutions to reform DoD's acquisition process. Each program is unique and thus requires unique solutions to its problems.

At the micro level, though, there are actions DoD can take to improve its performance in delivering MDAP capabilities to the warfighter. Legislative relief will not magically allow a program to perform to its requirement. Oversight does cause a burden to a program but it is not the root cause of program failures. The root cause lays in the requirement itself, and the desire to push programs forward before the technology is mature. The requirement drives the entire acquisition system and is the foundation of a program. Failing to build a program on a solid foundation and match the requirements to the technology weakens the foundation and introduces instability into a program. If not addressed at the root, the program's instability will increase causing delays and overruns until a program is canceled or restructured. The solution to this issue rests solely upon DoD to control.

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sequentially to reduce risk. In an effort to regain lost schedule time due to problems a program will frequently begin overlapping events such as technology development and EMD. In the case of the F-35 there is technology development, EMD, production, and testing concurrencies. As new faults are found during testing they must be repaired throughout the fleet of those already produced. This can be especially expensive and time consuming if the change requires structural reengineering as demonstrated in Tony Cappacio's previously cited article, "Lockheed Martin F-35 Jets May Cost U.S. \$1.26 Billions for Fixes."

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