Performance-Based Logistics: Examining the Successes and Challenges when Operating in Stressful Environments

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Table of Contents

Executive Summary

Given current and anticipated budgetary constraints, the Department of Defense (DoD) must heighten its focus on affordability, especially with regard to operations and maintenance costs, which account for almost two thirds of the defense budget. At the same time, new and evolving threats demand superior technology that is highly reliable. To a large extent, these twin objectives—reduced costs and better performance—can be achieved through the wider implementation of performance-based logistics (PBL) contracting, a proven strategy to obtain economical and innovative support solutions. Unfortunately, however, PBL contracting is not being aggressively pursued across the DoD.

Rather, the number of PBL-supported systems has declined. In 2005, there were more than 200 PBL contracts in place within the DoD. By 2013, the number of PBL contracts had dropped to 87, while total DoD sustainment costs continued to increase (Irwin, 2013). We believe that while PBL may appeal to users and program officials from a theoretical standpoint, some may be reluctant to embrace this strategy for fear that PBL arrangements may falter when supported systems are deployed in contingency and combat operations.

This perception manifests itself in a number of ways. For instance, some question whether the PBL mechanism is flexible enough to adapt to rapidly-changing conditions, that perhaps PBL works—until it doesn't. There is also concern over whether contractors will be able to perform at the same high level during contingency and combat operations, especially if these providers are deployed in theater. To address the validity of these claims, we examine four combat systems: the H-60 Seahawk helicopter, the High Mobility Artillery Rocket System (HIMARS), the Apache AH-64 helicopter, and the Stryker Armored Combat Vehicle.

Not only are these among the most deployed PBL-supported systems in combat, they represent a diversity of PBL arrangements with regard to contract type, terms, and length. For instance, the H-60 program encompasses a suite of PBLs that cover different subsystems, while the Apache PBL covers one component—the integrated targeting and night vision system. In both cases, the required maintenance is performed primarily by military personnel, with contractors responsible for supply chain operations and parts requisition. In contrast, both the HIMARS

and Stryker programs relied on contractors working in theater with military personnel to perform maintenance and repair.

It is noteworthy that these two programs reverted to the use of a traditional support strategy for some functions; The Stryker program now relies on soldiers, not contractors, for maintenance and repair, both at home and in theater, while HIMARS shifted to organic inventory management. Needless to say, these developments add to the perception that the PBL mechanism may not be a practical support solution for highly-deployed systems. We address this concern through a detailed examination of the history, attributes, and, performance of these four PBL programs.

H-60 Seahawk

The H-60 is the U.S. Navy's family of multipurpose twin-engine, medium-lift helicopters—the legacy SH-60B, SH-60F, HH-60H and the new MH-60R and MH-60S. The MH-60R, first deployed in 2009 to aid in Operation Iraqi Freedom, is a multi-purpose aircraft with many missions, including vertical replenishment, search and rescue, special operations support, and mine countermeasures, though its primary mission is anti-submarine and surface warfare. In 2002, the Navy sought a new product support strategy. To this day, the Navy relies on a suite of fixed-price PBL contracts that, in effect, cover maintenance and repair of the entire aircraft. The largest of these, the Tip-to-Tail (T2T) PBL program, supports over 1,200 parts (avionics and airframe).

The original five-year T2T contract covered legacy models. It was awarded to a joint venture between Lockheed Martin Systems Integration (LMSI) and Sikorsky Aircraft Company in December of 2003. Valued at approximately $417 million, the PBL provided requisition processing, requirements forecasting, inventory management, repair, overhaul, modification, packaging, handling, storage, transportation, configuration and obsolescence management, and reliability and technology improvement (Lockheed Martin, 2004). In order to capture contractor performance in the provision of these tasks, the PBL relied on a single metric—fill rate, which measures the percentage of requisitions filled on time.

Following the expiration of the initial contract, the Navy sought the use of contractor cost data in order to develop the basis for the fixed-price follow-on contract. Following a series of challenging negotiations, the contractor supplied the data and in December, 2010, the T2T was renewed for four years at an estimated five-year projected cost of $1.4 billion (Sikorsky, 2011). As the price increase indicates, the contract was expanded to cover the newer models, the MH-60 R and S.

Since its implementation, the PBL has exceeded the established minimum fill rate (80%), averaging a rate of 88% (19% above the pre-PBL rate). Furthermore, the fill rate for special management items, has also increased, 80 to 99%. In addition, backorders were reduced by over 90% (Skotty, 2005).

HIMARS

HIMARS is a wheeled, agile, rocket and guided missile launcher. The Army awarded the first HIMARS PBL contract to Lockheed Martin in the amount of $96 million in February 2004 (Lockheed Martin, 2003). HIMARS has been deployed extensively since PBL implementation in 2004, playing a significant role in operations in the Al Anbar province of Iraq. In January 2016, Lockheed Martin announced that HIMARS had reached one million operational hours with U.S. forces (Lockheed Martin, 2016).

By 2011, Lockheed Martin was supporting 620 Army and Marines fielded mobile launcher systems—396 HIMARS and 224 MLRS M270A1. A third PBL contract in the amount of $158 million extended HIMARS sustainment through December 2013 for services, and through December 2014 for hardware. The PBL strategy relied on firm-fixed-price with incentive fee contracts for stateside operations and cost-plus fixed fee contracts for overseas contingency operations (Gardner, 2008). This strategy provided strong cost reduction incentives as well as the flexibility to meet overseas contingency requirements.

The PBL contract required that system readiness be maintained at or above 90%, and that response time fall within a specified range a certain percentage of the time, depending on the nature of the problem. For overseas operations, the response time ranges were extended to provide the flexibility necessary to meet fluctuations in demand that might arise in unpredictable operating environments (DoD, 2006).

The program consistently achieved these objectives at the required percentages, with the relative simplicity of the performance requirements facilitating straightforward monitoring and, thus, complete transparency. The HIMARS PBL program achieved success early on, reaching a 99% average system readiness rate, with no launcher out of service for more than 24 hours (DoD, 2006). Since the program's inception, the PBL has consistently exceeded performance requirements.

In 2015, the DoD transitioned inventory management from the contractor to the government in an effort to further reduce costs. It remains to be seen whether the DoD's decision will lead to lower costs and continued high performance.

AH-64 Apache

The AH-64 Apache is a high powered, tank killing, attack helicopter. It was developed to repel conventional ground forces during a soviet invasion of Europe. Still an essential part of the Army's fleet today, the primary mission of the Apache is to perform armed reconnaissance and conduct rear, close, and shaping missions, including deep precision strikes.

Central to the Apache's mission is the Modernized Target Acquisition Designation Sight/Pilot Night Vision Sensor (M-TADS/PNVS) system, nicknamed the "eye of the Apache." The system, consisting of two sub-systems, enables Apache pilots to fly at low altitudes in total darkness and poor weather conditions, while also providing the capability for the co-pilot to identify and engage hostile targets (Cothran, 2012).

Since 2007, Lockheed Martin has provided sustainment for the AH-64 Apache Helicopter's M-TADS/PNVS system. The Apache sensors PBL relies on a firm fixed-price contract that is tied to the number of flight hours. This structure is ideally suited to heavily-deployed systems, such as the Apache, in that it provides the contractor with the traditional incentives associated with fixed-price contracts, translating to higher levels of innovation, reliability, and availability; at the same time, however, the contract is flexible, which ensures that the system is capable of supporting changes in operational tempo without unduly impacting tactics and strategy. The first four-year contract was valued at approximately $380 million; in 2012, a similar follow-on contract valued at $375 million was awarded (Lockheed Martin, 2012).

Lockheed has consistently achieved a supply availability rate of approximately 97%. The contract established a system of continuous improvements supporting the Apache sensors and covered complete post-production supply chain management, including inventory management, maintenance, modifications, procurement, repairs, and spares planning of fielded systems.

Annual sustainment costs prior to the implementation of PBL totaled $218 million per year. In 2013, costs totaled $92 million, a drop of 58%. Other accomplishments include the mitigation of 759 obsolescence and diminishing manufacturing cases since 2007 resulting in $104.2 million in cost avoidance, the reduction of the maintenance support footprint, and a decrease of over 1,000 maintenance man hours per year through increased materiel reliability (OSD, 2012).

Stryker

The DoD's first new vehicle since the early 1990s, the M1126 Stryker Combat vehicle is a rapidly-deployable wheeled armored vehicle, combining mobility, survivability, and versatility in combat environments with firepower and reduced logistics requirements (Gordon, et al., 2015).

The Stryker PBL was first implemented in 2002; in 2007 and 2012, follow-on contracts valued at $1.5 billion and $2.5 billion, respectively, extended support for an increasing number of vehicles (McLeary, 2014). Given the Army's heavy reliance on Stryker during these conflicts, the use of PBL, if successful, would go a long way in legitimizing PBL as a leading support strategy for deployed systems.

Under the PBL contract awarded in May of 2002, General Dynamics assumed responsibility for the ordering, management, and distribution of all spare parts, as well as provision of any and all vehicle maintenance services. Contractor personnel performed an array of functions including wheeled vehicle mechanics, armament repairer, or automated logistics specialists.

The PBL contract required a monthly readiness rate of 90% during deployments. Stateside, a 98% monthly rate was used during training exercises. Stryker continuously exceeded expectations, achieving, for example, 95% cumulative readiness during the height of the war in

Iraq—a war in which Stryker vehicles were driven in excess of 6.5 million miles (Coryell, 2007).

In November of 2005, citing a need for increased flexibility in different combat environments, the Army determined that soldiers, as opposed to contractors, would perform unscheduled maintenance for all Stryker vehicles. The Army's plan called for replacing 45 Stryker vehicle maintenance contractors with 71 soldiers. This transition relied on the Army's ability to annually recruit or retain 497 additional soldiers with specific military specialties to support all seven Stryker brigades (GAO, 2006). The GAO questioned the Army's plan, asserting, ironically, that the larger logistics footprint could negatively impact Stryker's deployment flexibility. In 2006, the Army began the transition, which, at present, is still underway.

Findings

In order to ensure the nation's continuing technological superiority and better prepare for the rapidly-changing global environment, the DoD must strive to reduce life cycle costs, improve system availability, and incentivize innovation.

Based on our examination of the PBL mechanism, its proven applications, and four PBL-supported systems, we provide our findings.

1. PBL-supported systems operating in stressful environments are capable of meeting or exceeding performance requirements, contributing to mission success.

In all four cases, the PBL programs met or exceeded performance requirements in operational availability and readiness. In light of new and emerging threats, a program's proven ability to consistently meet high performance standards in excess of 90, 95, or 99% availability/readiness cannot be overstated.

2. PBL contractors have the proven ability to support weapons systems operating in stressful environments.

These cases demonstrated that PBL contractors are willing and able to perform a critical supporting role, even in stressful environments.

3. PBL provides sufficient flexibility and capacity to adapt to changing operational tempos.

The four cases suggest that PBL programs are adaptable and scalable, provided that they are structured appropriately. PBLs relying on cost-plus contracts provide inherent flexibility (to the government and the contractor) in the face of uncertainty, both technical and operational. Fixed-price PBLs also provide flexibility, especially when price is tied to operational tempo (number of flight hours, miles driven).

4. All support contracts, including PBLs operating in theater, should apply stringent cost controls.

Carefully-considered contract ceilings, cost-per-unit usage rates, and logistics footprint constraints should be included in cost-plus contracts. Without these features, contractors may be incentivized to accrue surplus inventory beyond what is necessary to meet the performance requirement.

Recommendations

Based on these findings, we provide the following recommendations to the DoD.

1. Promote the use of PBL as a proven support strategy for weapons systems.

PBLs perform better than traditional support mechanisms, even in stressful environments. The DoD should renew its commitment to the expansion of PBL in order to improve weapons systems operation and reduce costs.

2. Ensure proper alignment of government objectives with provider incentives.

PBL agreements can be more challenging to develop and manage than other contract types. Just as an appropriate PBL program structure aligns the incentives of the customer (the government) and the support provider, leading to a win-win scenario, an inappropriate structure can create perverse incentives, and result in undesired or unintended consequences.

3. Structure PBL contracts appropriately

In environments characterized by relatively low levels of uncertainty, both operational and technical, alignment of contractor and government objectives is optimized under fixed-price PBL contracts. However, in stressful, unpredictable environments, cost-plus PBL contracts are often more suitable in that they provide greater flexibility to meet mission objectives. In these circumstances, however, programs may need to employ additional metrics beyond reliability and availability, including cost-per-unit usage rates and logistics footprint constraints, in order to strike the optimal balance between required availability and cost.

4. Avoid distortions to the PBL paradigm

From a theoretical standpoint, the power of PBL lies in affording the provider the discretion and flexibility to select the optimal mix of inventory levels, maintenance activities, and technology upgrades in order to meet performance requirements. Shifting one or more of these functions to the government customer distorts the PBL paradigm and may lead to reductions in performance and higher costs.

Conclusion

The case studies suggest that deployed units sustained through PBL programs are capable of exceeding performance and cost requirements, often outperforming weapons systems in garrison.

Ultimately, we found little to justify the notion that PBL programs, when properly-implemented, have trouble performing in stressful environments. Our findings indicate that the DoD would be well advised to expand the use of PBL for the sustainment of weapons systems.

I. Introduction

Faced with a rapidly changing global environment and unpredictable threats, the United States has been examining alternate means of acquiring and maintaining weapons systems. Given current and anticipated budgetary constraints, the Department of Defense (DoD) must heighten its focus on affordability, particularly with regard to operations and maintenance costs—which have accounted for almost two thirds of the defense budget in recent years.

Performance-based logistics (PBL) has proven to be a valuable tool in the DoD's search for a more economical and innovative logistics support solutions. Boasting a range of benefits from drastically reduced costs to increased weapon system reliability, PBL has the proven potential to help the DoD achieve several of its acquisition objectives. Yet despite being named the DoD's preferred weapon support strategy in 2001, PBL contracting is not being aggressively pursued across the DoD.

We believe that although PBL contracts may appeal to users and program officials from a theoretical standpoint, some within the DoD may be reluctant to embrace this strategy for fear that PBL arrangements may falter when supporting deployed systems in contingency and combat operations.

These concerns manifest themselves in several ways. For instance, some question whether the PBL mechanism in itself is flexible enough to adapt to rapidly-changing conditions, in other words, that PBL works—until it doesn't. Furthermore, concerns have been raised over whether or not contractors will be able to perform at the same high levels during contingency and combat operations as they do in garrison, particularly if these providers are deployed in theater. Some have also questioned the availability of contractor personnel who are willing to operate in combat and high stress environments. To address the validity of these claims, we examine the performance of four PBL sustainment programs that have operated in stressful environments.

According to a 2007 Congressional Budget Office (CBO) report, during the conflicts in Iraq and Afghanistan, major weapons systems typically operated at rates that exceeded—at times by factors of five or six—their average operating rates during peacetime (CBO, 2007). Chief among these systems were combat vehicles and helicopters, systems that require the highest levels of repair and reconditioning. We examine four such systems: the H-60 Seahawk helicopter, the High Mobility Artillery Rocket System (HIMARS), the Apache AH-64 helicopter's Modernized Target Acquisition Designation Sight/Pilot Night Vision Sensor (M-TADS/PNVS), and the Stryker Armored Combat Vehicle.

Not only are these examples among the most deployed PBL-support systems, they also represent a diversity of PBL arrangements with regard to contract type, terms and length. The H-60 program, for example, encompasses a suite of PBL's that cover different subsystems, while the Apache PBL covers only one component of the aircraft – the fire control system. In both cases, the required maintenance is performed by military personnel, with contractors responsible for supply chain operations and parts requisition. In contrast, both the HIMARS and Stryker programs relied on contractors working in theater with military personnel to provide technical support. It is noteworthy that these two programs would later revert to the use of a traditional support strategy for some functions; the Stryker program now relies on organic support—with soldiers, not contractors, providing maintenance and repair functions both at home and in theater, while HIMARS shifted to organic inventory management. Needless to say, these developments inadvertently add to the perception that the PBL mechanism may not function as a practical support solution for highly deployed systems. Ultimately, we address these concerns through a detailed examination of the history, attributes, and overall performance of these PBL programs.

Report Approach

In Part II of this report, we examine the DoD's budgetary outlook in order to gauge the ability to provide for the maintenance and repair of major weapons systems using traditional sustainment strategies. We then provide an overview of performance-based logistics. In Part III, we provide an in-depth examination of PBLs that have operated in stressful environments. In Part IV, we provide a summary of our findings and recommendations.

II. Background

In this section, we examine the DoD's budgetary outlook, which has prompted its transition to performance-based services contracting, a trend that is accelerating across both the public and private sectors. We then provide a brief overview of performance-based logistics wherein we contrast the theoretical and empirical evidence of PBL's success against statistics on its declining use.

Budgetary Outlook

As the wars in Iraq and Afghanistan have drawn to a close, the United States has been faced with a challenging, and rapidly changing, defense environment. Shrinking defense budgets, paired with constant changes in the character and demands of modern warfare have intensified the need for a modern approach to logistics. The fact that total defense spending (in real terms) was higher in 2010 than at any point since the end of World War II (See Figure 1) suggests to critics that the military could further decrease the number of troops and reduce the scope of acquisitions.

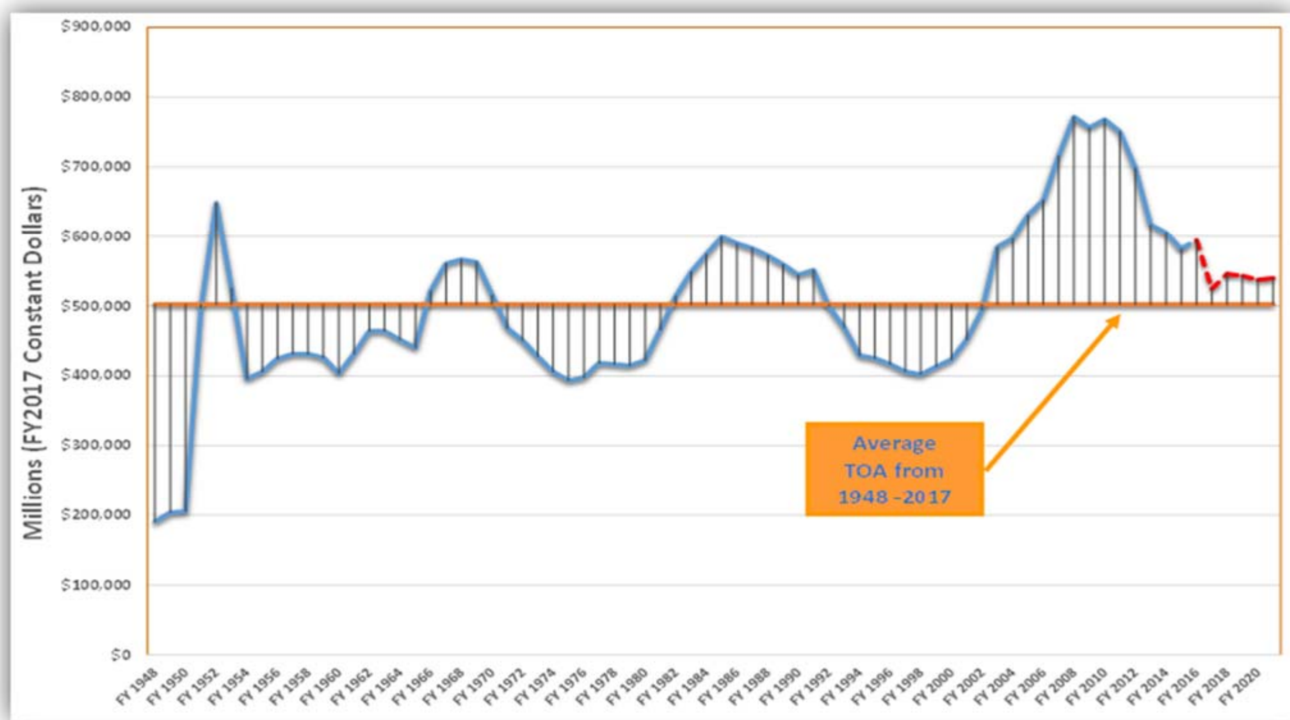


Figure 1. DoD Total Budget Authority Trends (1948-2017)
Note. The information in this figure comes from the DoD's FY 2017 Green Book (DOD, 2016)

Yet even then, active-duty military end-strength had dropped to near all-time post-Cold War lows (See Figure 2). Over the last five years, defense spending has decreased precipitously. Figure 1 is characterized by peaks and troughs that correspond to the lead up and draw down of major U.S. involved conflicts. If past trends are any indication, spending may continue to fall now that major involvement in overseas contingencies has dramatically decreased. All the while, equipment inventories are becoming older, smaller, and less effective against emerging technologies.

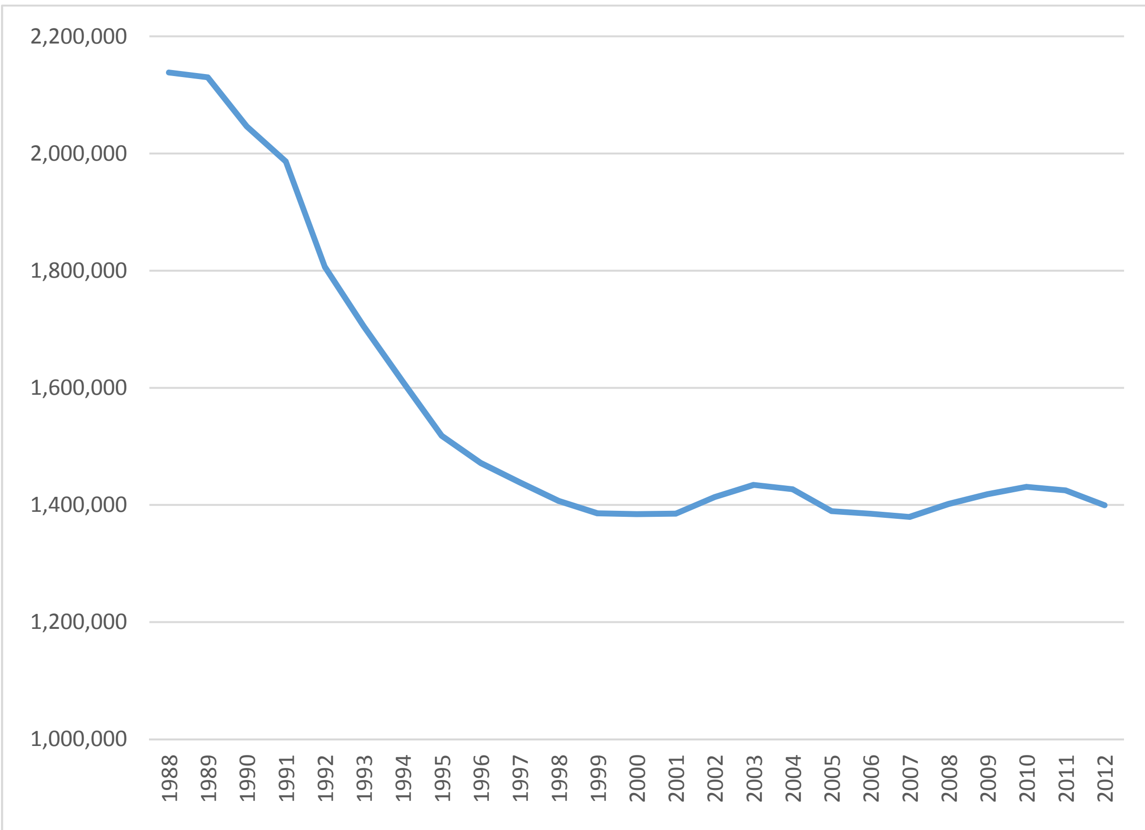


Figure 2. Total active duty military end strength (1988-2012)
Note. The information in this graph came from CSIS (CSIS, 2015)

It is within this challenging environment that the DoD must seek to reduce its operations and maintenance costs, which will increase to close to $250 billion by 2020 (CBO, 2012; See Figure 3). Weapons sustainment is a significant driver of these costs. For instance, the DoD requested over $14 billion to fund depot maintenance in FY 2015, which is $986 million (7%) more than the amount spent in the previous year (DoD, 2014). Properly-implemented PBL strategies have the potential to reduce these and other sustainment-related costs.

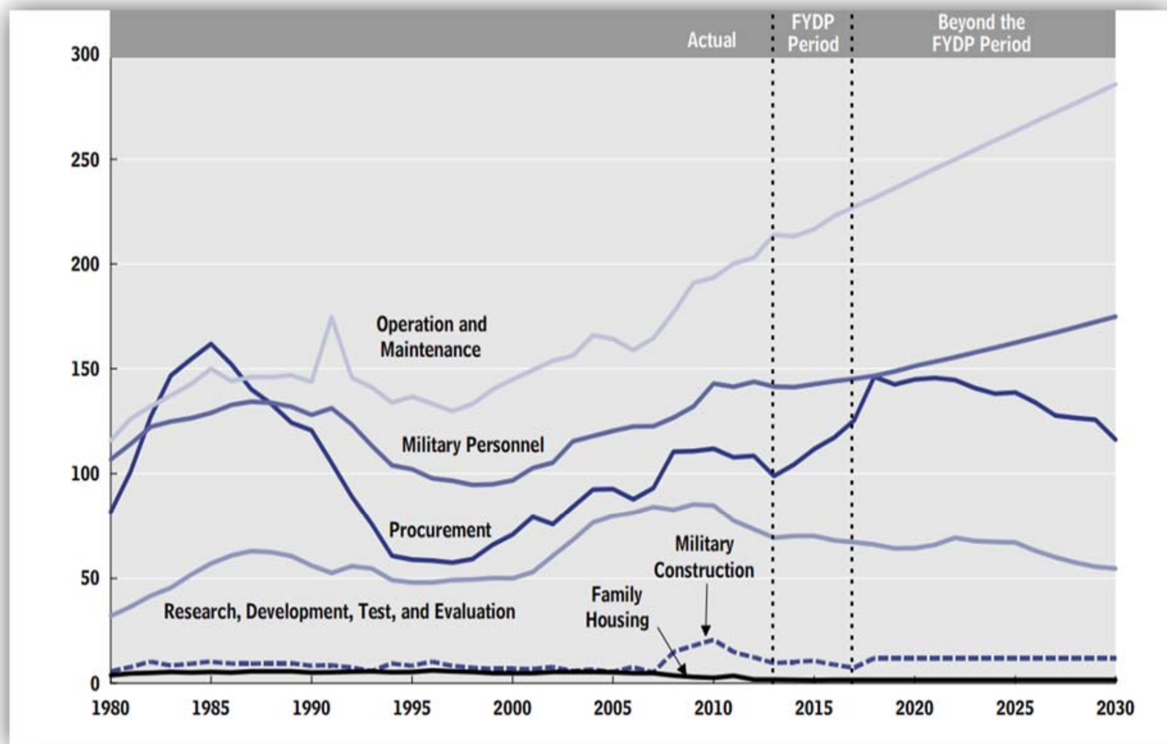


Figure 3. The DoD's costs (2013 billions of dollars) by appropriation category (CBO, 2012)

Performance Based Logistics

Over the last decade, the DoD has focused on reducing the cost of weapons system development, in addition to the products and services that it purchases, by crafting more sophisticated contracts with more favorable terms for the government (Butler, 2013). In addition, the services are increasingly diverting their attention to sustainment costs—which are continuing to increase across the DoD—in part because systems are aging more rapidly because the services cannot afford to buy replacements.

The DoD has identified PBL as its preferred approach to supporting weapon system logistics. PBL contracting, when used appropriately can reduce sustainment costs relative to traditional, transactional approaches. PBL is a logistics support solution that transfers inventory management, technical support, and the supply chain function to a provider who guarantees a level of performance at the same or reduced cost. Instead of buying spares, repairs, tools, and data in individual transactions, PBL entails the purchase of a predetermined level of availability that meets the warfighter's objectives.

In most cases, PBL contracts are multi-year agreements wherein the selected provider manages a given system's supply chain. Whereas traditional sustainment contracts incentivize the provider to sell parts, PBL's "pay for performance" approach, when structured appropriately, motivates the provider to reduce failures and resource consumption.

Furthermore, because most PBL contracts last between 5 and 15 years, they create long term partnerships and stronger relationships with industry—leveraging commercial best practices and increasing availability and reliability, while reducing the logistics footprint and costs.

As outlined in the Defense Acquisition Guidebook, performance is defined by the following criteria.

1. **Operational Availability:** Percent of time that the system is able to sustain operations tempos or is available for missions
2. **Operational Reliability:** Measure of a system in meeting objectives set for mission success
3. **Cost per Unit Usage:** Total operating costs divided by the individual unit of measurement for a specific weapons system (flight hour, miles driven, etc.)
4. **Logistics Footprint:** Government or contractor presence required to sustain/deploy the system
5. **Logistics Response Time:** Time from logistics demand sent to completion of demands (labor, support, etc.)

When implemented, PBL shifts the focus of the government's efforts from transactions to identifying performance outcomes and assigning responsibilities. The objective is to develop accountability, instead of relying on control. With PBL, active management of the sustainment process (e.g. forecasting demand, maintaining inventory, and scheduling repairs) becomes the responsibility of the support provider. Additionally, it changes the incentives for the supplier. The supplier, with a properly structured PBL program, is now incentivized to improve the reliability of systems, and reduce inventories of spare parts; and with fewer repairs made and fewer parts sold, the contractor stands to make more profit—while from the government's perspective, PBL results in optimizing total system availability, and, at the same time, minimizes the cost and the logistics footprint (Gansler & and Lucyshyn, 2006).

PBL programs frequently rely on commercial sector supply chains which are fully-integrated, end-to-end, systems. Unfortunately, comparable systems do not exist within the DoD. The DoD's traditional approach has been fragmented, with segmented accountability and control by various stakeholders (Defense Logistics Agency, services, and depots) all of which have their own budget requirements and restrictions, and different priorities. Additionally, the responsibility for the elements of logistics has been shared between acquisition activities and sustainment activities. Traditional logistics metrics are focused on internal logistics processes, and rarely have a direct relationship to warfighter requirements. Moreover, efforts to optimize these elements often results in sub-optimal results at the system level (Devries, 2004).

Additionally, traditional logistics support dictates processes and design specifications, which has the effect of restricting innovation and process improvements. Suppliers and equipment manufacturers are also incentivized to sell more repair parts, versus developing and implementing reliability improvements. As a result of these factors, it is difficult to provide truly cost-effective, integrated logistics support using the DoD's traditional model.

There is no doubt that the DoD must move away from its traditional hierarchical command and control structure towards a more adaptive system that will provide the precise, agile support required for the distributed, network-centric operations that the DoD envisions. In addition to the logistics benefits, there are four distinct advantages associated with the use of PBL contracting, listed below:

- <u>Delineates outcome performance goal.</u> The objective of PBL programs is to buy measurable outcomes based on warfighter performance requirements.
- <u>Ensures responsibilities are assigned.</u> PBL metrics, when properly developed, define the suppliers' responsibilities very clearly.
- <u>Reduces cost of ownership.</u> This reduction results from the decline in inventories, improved supply chain efficiency, replacement of low-reliability components, and increased system availability.
- <u>Provides incentives for attaining performance goal.</u> The PBL program should fundamentally align the interest of the supplier with that of the customer, and lead suppliers to assume greater responsibility for providing ongoing improvements to their

products. PBL provides incentives for the supplier to improve design and processes and implement commercial best practices (Gansler & and Lucyshyn, 2006).

There is ample empirical data that demonstrates that PBL, when properly implemented, produces desired outcomes in the key performance areas of availability, reliability, logistics footprint, and cost. Major systems including the C-17 and F/A-18, for instance, have all reduced sustainment costs by hundreds of millions of dollars, while other systems and subsystems such as the F-22 , UH-60 avionics, and F-404 engine have seen drastic improvement in availability and cycle time (i.e. logistics response and repair turnaround; (Fowler, 2008). Other government reports (e.g. Office of the Secretary of Defense, 2009) and think-tank studies have concluded that PBL offers distinct benefits that are difficult to achieve using traditional approaches. The question, then, is why is PBL not being aggressively pursued across the DoD?

The number of PBL-supported systems has declined over the last several years. In 2005, for example, over 200 PBL contracts were in place within the DOD, with spending on such contracts having more than tripled since their inception—from approximately $1.4 billion in 2001 to $5.0 billion in 2009. By 2013, however, the number of PBL contracts had dropped to 87, while total DoD sustainment costs continued to increase (Erwin, 2013). We believe that although PBL contracts may appeal to users and program officials from a theoretical standpoint, some within the DoD may be reluctant to embrace this strategy for fear that PBL arrangements may falter when supporting deployed systems in contingency and combat operations.

III. Cases

In the four cases that follow, we examine the performance of four highly-deployed systems that have operated in stressful environments in an effort to determine whether this reluctance is justified. We begin with the H-60 Seahawk which relies on the "Tip-to-Tail" PBL to provide support for over 1,200 parts and components. We then examine the High Mobility Artillery Rocket System (HIMARS) followed by the Apache helicopter, two PBLs that provide subsystem-level support. The HIMARS PBL supports two major subcomponents, the Launcher-Loader Module and the Fire Control System. The Apache PBL supports the Modernized Target Acquisition Designation Sight/Pilot Night Vision Sensor (MTADS/PNVS), referred to as the "Arrowhead." Finally, we examine the Stryker armored vehicle which relies on a PBL to provide support for the entire system.

H-60 Seahawk Helicopter

The H-60 is the U.S. Navy's family of multipurpose twin-engine, medium-lift helicopters—the legacy SH-60B, SH-60F, HH-60H and the new MH-60R and MH-60S. The MH-60R conducts anti-submarine and surface warfare. The MH-60S is a multi-purpose aircraft with many missions including vertical replenishment, search and rescue, special operations support, and mine countermeasures. The two variants share upgraded mission systems, avionics, and components, including a common cockpit that allows pilots to shift from one aircraft to another with minimal retraining. Both contributed in a number of roles during Operation Iraqi Freedom.

A Brief History

The first Navy version of the H-60 Seahawk entered service in 1983. The SH-60B Seahawk, and the second-generation SH-60F and HH-60H, have been relied upon as the Navy's workhorse helicopter for over 20 years. Formally introduced to the fleet in 2002, the first MH-60R squadron deployed in 2006, with the first aircraft carrier deployment in 2009. Per the Navy's modernization plan, the legacy versions will eventually be replaced in their entirety by the R and S variants.

Prior to 2002, the H-60 relied on organic sustainment and maintenance, the provision of which was complicated by the number of versions that were in service, the length of their service, and the introduction of the two new models. The high operational tempo of the aircraft, combined with the unique challenges of maintaining rotary wing aircraft (e.g. the corrosive effects of maritime operations), led to increasing operating and support costs, and lower availability (Heron, 2010). Obsolete parts represented an additional problem; sustainment and maintenance necessitated the repair of small batches of custom-made parts, often at high cost, or the undertaking of expensive engineering changes to the aircraft to enable the use of newer parts.

A 1996 GAO report noted that one specific part "had a repair time of 232 hours, only 20 hours of which was spent actually repairing the item, [and that] the remaining 212 hours involved time to handle and move the part to different locations" (GAO, 1996). And in 2004, NAVICP asserted that "the SH-60F/B and HH-60H aircraft continue to experience increasing reliability issues, resulting in decreased readiness levels [due to the] inability to address obsolescence issues" (GAO, 1996).

Program Description

In 2002, the Navy sought a new product support strategy for the H-60. The Navy now relies on a suite of fixed-price PBL contracts that effectively cover maintenance and repair of the entire aircraft. The largest of these, the Tip-to-Tail (T2T) PBL program, was initiated in 2003 and, under the current contract, supports over 1,200 parts (avionics and airframe) for the five H-60 models. The prime contractor is the Maritime Helicopter Support Company (MHSCo), initially a joint venture between Lockheed Martin and Sikorsky Aircraft. Lockheed purchased Sikorsky in 2015.

Lockheed Martin was the original integrator for the SH-60B and an original equipment manufacturer (OEM) for the MH-60R/S avionics. Sikorsky is the OEM for the SH-60F and HH-60H avionics and the H-60 airframe. As the prime integrator and OEM for H-60s, Lockheed and Sikorsky already owned the required technical data. With the H-60, the sub-systems and components are integrated, so if either company were awarded the T2T independently, it would, by necessity, have had to collaborate with the other company; hence, the two companies formalized a partnership by establishing MHSCo.

The PBL provides requisition processing, requirements forecasting, inventory management, repair, overhaul, modification, packaging, handling, storage, transportation, configuration and obsolescence management, and reliability and technology improvement (Lockheed Martin, 2004). MHSCo coordinates all of these functions, directly managing the supply chain, warehousing, and transportation; however, it does not repair or manufacture any parts directly. Rather, MHSCo relies on a network of over 30 private sector suppliers as well as government depots that specialize in the repair and maintenance of H-60 aircraft. MHSCo has public-private partnerships (PPPs) with Flight Readiness Center (FRC) Southeast, FRC East, Corpus Christi Army Depot, FRC Southwest, and Tobyhanna Army Depot that provide key advantages; these include expert artisans, specialized tools and equipment, and other logistical advantages (naval depots are often co-located with operational units, simplifying transportation and communication) (Berube, 2011). Major repairs are performed by the OEMs and the PPPs. The PBL increased reliance on intermediate-level repairs by funding FRC specialists to assist aboard ship with Aircraft Intermediate Maintenance Departments, reducing the logistics footprint, increasing availability, and reducing costs.

According to program officials, the key to success in this program is “management by exception.” The program uses an algorithm that was developed to automatically mine data collected and stored in the program’s SAP-based Management Information System, tailored specifically for T2T. This algorithm takes real-time performance data on demand rates, demand rate variability, repair turnaround time, and inventory levels, and flags those parts that may be at risk for backorders. The MIS interfaces with Navy logistics systems and helps inform both internal and external decision-making. The MIS automates and monitors requisition processes, thereby increasing control and lowering costs.

PBL Strategy

Awarded in December of 2003, the original five-year, firm fixed-price T2T contract covered over 500 parts for the legacy H-60 models. It was valued at approximately $417 million (Lockheed Martin, 2004). The fixed-price is tied to the number of flight hours and relies on the metric of supply availability, which measures the percentage of requisitions filled on time. This contract was modified over time to support over 1,200 parts in 2008 for a total contract value of $900 million.

Following the expiration of this contract, the Navy sought the use of contractor cost data in order to develop the basis for the follow-on contract. MHSCo was naturally resistant, worried that the Navy might seek to use the data to set profit levels. The Navy and MHSCo also disagreed over the length of the proposed contract and the role of competition. The Navy sought a shorter-term contract, MHSCo a longer, five-year contract. Unable to come to an agreement, the two parties signed “bridge” contracts in 2009 and again in 2010.

Following a series of challenging negotiations, the contractor supplied the cost data and in December of 2010, the T2T was renewed at an estimated four-year projected cost of $1.4 billion which represents a savings to the Navy of approximately $60 million over the initial contract (Garvey, 2011). The firm fixed-price contract (no options), priced at $500 million over the initial contract, was expanded to cover the new MH-60 R and S, supporting a total of 490 legacy and new H-60 helicopters. In fact, the contract was the largest single contract ever awarded by NAVICP and the Navy Supply System. Furthermore, it was the only platform-level PBL awarded by the Navy in 2010 (Aviation Week, 2011). A third contract, with a five year period of performance and valued at approximately $2 billion, was awarded in 2015.

To meet the minimum supply availability requirement (which the program referred to as fill rate and, in the two more recent contracts, supply response time) of 80%, the program uses a matrix consisting of four variables—issue group, priority, location, and weight limit (Skotty, 2005). Figure 4 depicts the matrix used for CONUS operations under the first contract. The nature of the problem (issue group) and its assigned priority level in combination with the weight of the covered part or component are used to determine allowable delivery timeframes. MHSCo must supply the part or component within the allowable timeframe 80% of the time.

As with the contract structure itself, which ties the contract price to the number of flight hours, the supply availability requirement matrix injects considerable flexibility into the program while aligning contractor priorities with those of the Navy.

Issue Group	Priority	CONUS Delivery Timeframes	
		≤ 150 lbs	> 150 lbs
1	01 – 03	2 Business Days	4 Business Days
2&3	04 – 08 & 09 – 15	5 Business Days	

Figure 4. T2T PBL Supply Availability Requirement Matrix, T2T PBL (Skotty, 2005)

PBL Results

Since its implementation, the PBL has exceeded the established minimum fill rate (80%), averaging a rate of 88% (19% above the pre-PBL rate). Furthermore, the fill rate for special management items has also increased from 80 to 99%. In addition, backorders were reduced by over 90% (Skotty, 2012; See Figure 4).

Since the inception of the PBL, MHSCo has worked to improve availability, in part, improving parts reliability. Often, simple fixes had a considerable impact. For instance, rotary by blades left on the ground were being unintentionally stepped on, which damaged their honeycombed interior and rendered them inoperable. MHSCo mitigated this problem by the simple addition of “DO NOT STEP” decals to the blade.

A more elaborate process improvement occurred in changing the way blades are repaired. The U.S. Army, which has extensive experience with the H-60 helicopter, had a blade rebuild process superior to that of the Navy. Sikorsky, as the blade manufacturer, saw and compared the two rebuild processes, determining the Army’s method was superior, and introduced it to the Navy. Finally, a special nut used to attached the rotor blades to the rotor head was being stripped during routine maintenance; driving up demand for replacement nuts. MHSCo developed a special-purpose wrench, eliminating the stripping problem, and thus reduced the demand for frequent nut replacements. These sorts of process and reliability improvements reduced the demand rate for new parts and parts repair (See Figure 5) despite ageing legacy aircraft and higher OPTEMPOs during conflicts.

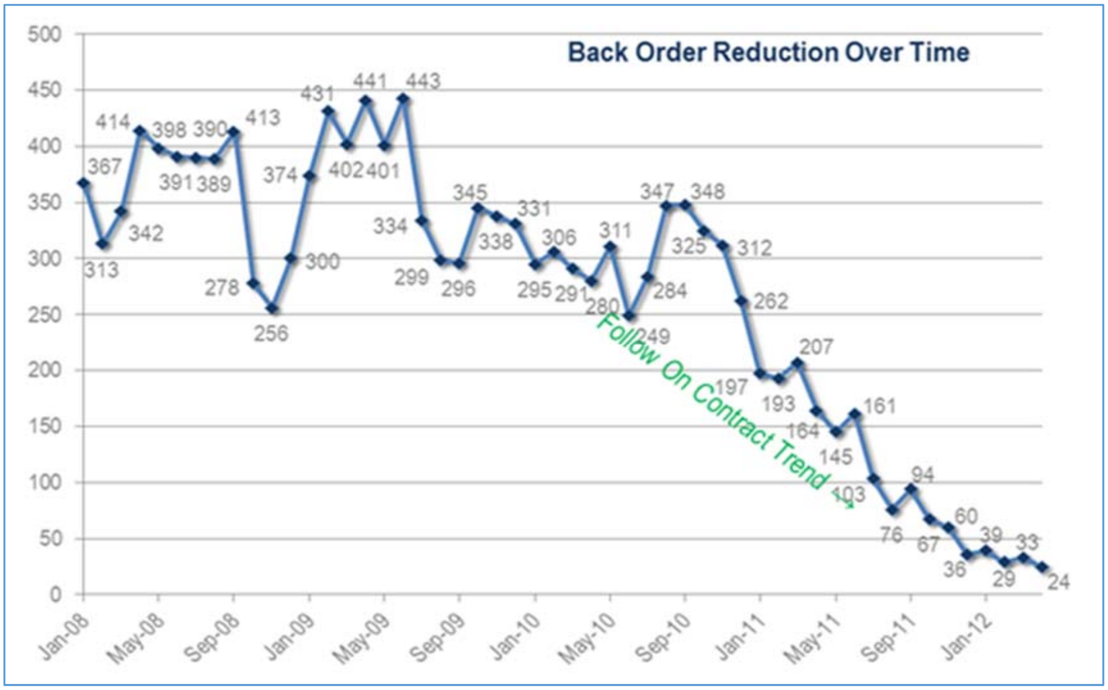


Figure 5. Back Order Reduction Over Time (Skotty, 2012)

For the original contract, NAVSUP estimated in 2008 that the T2T had saved the Navy $41M over five years. That is a savings of approximately 4.5% using the $900M total five-year program cost estimate. The Navy's business case analysis of the follow-on 2010 contract projected savings to the Navy of $46M over the five years of that contract. These represent significant savings.

HIMARS

The high-mobility artillery rocket system, better known as HIMARS, is the latest addition to the military's multiple-launch rocket system (MLRS) family. Designed with the purpose of engaging and combatting artillery, trucks, air defense, light armor and personnel carriers; it was a lighter, more mobile variation on the MLRS M270A1, with some common components. In addition

to supporting troop and supply concentrations; HIMARS has been in constant demand by both the Army and the Marine Corps, (as well as foreign governments) since the production of its first prototype in 1999 (Army-Technology, 2015) (Gansler & Lucyshyn, 2014).

Boasting a 99 percent operational readiness rate over the past decade, the HIMARS launcher is an impressive weapon that has continuously exceeded expectations. Initially developed through an advanced concept technology demonstration (ACTD) program by Lockheed Martin Missile and Fire Control in 1996, HIMARS has been referred to as "the most advanced artillery system in the U.S. arsenal." Following their successful deployments during Operation Iraqi Freedom, HIMARS launchers have become indispensable to the arsenals of both the Army and Marine Corps (Army-Technology, 2015) (Lockheed Martin, 2011) (Hiawatha World, 2015).

A Brief History

Originally conceived to meet the need for a lighter, rapidly deployable rocket launcher – HIMARS is a wheeled, agile, rocket and guided missile launcher fixed to a five-ton armored truck (Gansler & Lucyshyn, 2014). Owing to its wheeled chassis and lightweight design, the system can be easily transported by C-130, allowing it to be deployed to previously inaccessible areas at a moment's notice (Lockheed Martin, 2011). The HIMARS system has been internationally recognized for its highly efficient and innovative features, including the ability to take aim of a target in under 16 seconds, and rapidly move away from the launch site once a missile is released. In addition, its fire controls system, electronics, and communications units are interchangeable with its heavier, tracked, predecessor.

Following its initial development in 1996, Lockheed Martin was awarded an engineering and manufacturing development (EMD) contract for six launchers (and later an additional two launchers) in 2000 (Army-Technology, 2015). Not long after, in 2003, "the U.S. Army and Marine Corps signed a contract for the low-rate initial production (LRIP) of 89 launchers for the Army and four for the USMC" (Army-Technology, 2015). As the U.S. role in overseas conflicts grew in the mid to late 2000s, the need for additional HIMARS units grew quickly, as outlined in Figure 6.

HIMARS Timeline, 2004-2011	
January 2004	Second LRIP awarded • 25 launchers for the Army, 1 for the USMC
January 2005	Third LRIP awarded • 37 launchers for the Army, 1 for the USMC
November 2004	Initial operational test & evaluation (IOT&E) completed • Three prototype launchers used successfully for Operation Iraqi Freedom
June 2005	HIMARS enters service with 27th Field Artillery, 18th Airborne Corps at Fort Bragg • July 2007 – 2nd Battalion, 14th Marine Regiment deployed to Iraq
December 2005	First full-rate production contract
January 2007	Lockheed awarded contract for an additional 44 launchers for the Army, and 16 for the USMC
2008	HIMARS completes "255 out of 257 dry-fire missions and 17 out of 17 live-fire missions for a 99.2% and 100% success rate, respectively ("XM142", 2008) (Gansler & Lucyshyn, 2014)
January 2009	Contract placed for 57 launchers for the Army, and 7 for the USMC
March 2009	HIMARS launchers successfully fired two advanced medium-range air-to-air missiles
June 2010	BAE systems awarded $24 million contract for 63 HIMARS launchers • November 2010 – additional $16.3 million contract with US Army Tank Automotive and Armaments Command to supply 44 more HIMARS launchers
January 2011	$139.6 million contract between Army and Lockheed Martin for 44 combat-proven HIMARS • Total launchers = 375
September 2011	Army received its 400th HIMARS launcher

Figure 6. HIMARS Program Timeline (Army-Technology, 2015)

Since its introduction into the force in 1998, HIMARS has proven its value through both peacetime forcible-entry exercises and on operational deployments in the U.S. Central Command (CENTCOM) area of responsibility (Russo & Hilbert, 2008).

Program Description

The Lockheed Martin LCCS/LCLS program office is headquartered in Dallas, where numerous program functions are executed including program management, depot repair coordination, inventory control, contracting with suppliers, design interface, and database maintenance. The database tracks the location of each launcher, including each spare part, indicates whether the part is functional, and provides its status with regard to the repair process. The DoD's internal logistics systems rarely achieve this level of visibility, often leading to ordering redundancy, misplaced orders, and an incomplete picture of program operations.

There are also 26 field service representatives (FSRs) that operate from 22 locations, eight of which are overseas. In-theater maintenance work is performed primarily by soldiers, while the FSRs facilitate the supply process by overseeing numerous functions (Hawkins, 2009). These functions include

- supply, receipt, storage, issue, inspecting, packaging, and shipping, of subsystems and components;
- data collection and recording (maintenance actions, supply transactions, operating hours, munitions status [deployment and garrison]);
- system fault isolation using a variety of either built in or stand-alone test equipment;
- replacement of assemblies, as required;
- provision of technical assistance and support (both launcher and automotive); and
- provision of an interface for "reach back" engineering support, enabling the rapid resolution of problems.

Given the level of sophistication provided by the Lockheed Martin's database and logistics networks, the FSRs are able to streamline and simplify the repair process for launchers. As a result, early-on in the PBL program, Lockheed Martin was able to reduce the number of diagnostics devices provided to each battalion from six to one. In fact, soldiers operating the system in theater need only remove and replace defective components.

Perhaps one of the greatest benefits is the provision of limited depot-level repair capability at each battalion where repair work is provided by the FSR. Referred to as the capability to "Fix Forward," some 50% of all HIMARS repairs are performed on location by the FSRs, eliminating wait times and significantly reducing costs. Moreover, the FSRs are trained to test and replace circuit card assemblies (CCAs), rather than the LRUs in which they are housed, which reduces the overall logistics footprint—only the CCAs need to be shipped—and lowers costs. This in-the-field repair capability has also significantly improved deployed launcher availability. According to interviews with Lockheed Martin officials, FSRs voiced few concerns over their work environments, safety, or civilian status within the battalion, with several volunteering to return.

PBL Strategy

The Army awarded the first HIMARS PBL contract to Lockheed Martin in the amount of $96 million in February 2004 (Gansler & and Lucyshyn, 2006). The four-year contract, referred to as Life Cycle Contractor Support (LCCS) ended in December 2007. At this point, the Army had acquired 195 HIMARS launchers; and the Marines had acquired 40. Given its increasing inventory of HIMARS, the existence of a successful partnership between the Army and Lockheed Martin, and the cost benefits that derive from economies of scale, the Marines sought to support its launchers through LCCS upon completion of the initial contract.

Accordingly, the second contract (LCCS II), a three-year contract worth $90 million, was awarded in January 2008 to support both the Army and Marines' systems. The shorter duration of LCCS II reflected significant risk associated with unknown launcher production quantities and price fluctuations for component spares (Gardner, 2008). A third contract, in the amount of $158 million, termed Life Cycle Launcher Support (LCLS), extended HIMARS sustainment through December 2013 for services and through December 2014 for hardware.

The PBL strategy relied on firm fixed-price with incentive fee contracts for stateside operations and cost-plus fixed fee contracts for overseas contingency operations (Gardner, 2008).This strategy provided strong cost reduction incentives as well as the flexibility to meet overseas contingency requirements. Moreover, the fixed-price is tied to OPTEMPO category, with each vehicle assigned to a price category based on anticipated usage.

The LCCS contracts entrusted Lockheed Martin with the full support responsibilities for the performance-based product support of the HIMARS and MLRS M270A1 launchers' fire control systems, as well as the HIMARS launcher-loader module (Gardner, 2008). The commonality of support for the two platforms allowed the Army and later, the Marines, to maximize economies of scale in order to reduce costs (DoD, 2006).

The LCCS concept represented a significant evolution from the original M270 MLRS strategy, according to which the majority of tasks (e.g. initial provisioning, inventory management, war reserve stock, repair and overhaul, depot maintenance, etc.) were provided with organic support. LCCS, on the other hand, represents an ideal partnership, one in which the contractor assumes responsibility for providing technical support and user training in order to meet performance objectives while at the same time maximizing existing Army depot and acquisition infrastructure and relying on military personnel to operate the system.

Based primarily on data collection provided by Lockheed Martin during the initial contract, the LCCS team was able to make a number of changes to the LCCS II contract that would reduce future ownership costs. Notably, the team determined that the usage hours for the launchers varied significantly between active Army units and National Guard units (OSD, 2009). In an effort to reduce future costs, the less-used units were categorized under a lower operational tempo, which led to a reduction in needed support. Accordingly, Lockheed Martin and the DoD negotiated the LCCS II contract to reflect the anticipated savings derived through the reduction in operational tempo. These savings turned out to be considerable. In 2007—the final year of LCCS I—costs associated with operational tempo totaled $12.4 million; in 2009 these costs had declined to $3.8 million, for a total cost avoidance of $8.6 million.

The PBL required that system readiness be maintained at or above 90%, and that response time fall within a specified range a certain percentage of the time, depending on the nature of the problem. For overseas operations, the response time ranges were extended to provide the flexibility necessary to meet fluctuations in demand that might arise in unpredictable operating environments (DoD, 2006). The LCCS II contract required that system readiness be maintained at or above 90% and that response time be below 48, 72, or 96 hours for U.S. based operations, depending on the nature of the problem, 92%, 91%, and 90% of the time, respectively (OSD, 2009). For overseas operations, the response time had to be below 96, 120, or 144 hours (OSD, 2009).

PBL Performance

The HIMARS PBL program achieved success early on, reaching a 99% average system readiness rate, with no launcher out of service for more than 24 hours (Gansler & Lucyshyn, 2014). In addition to system readiness, the HIMARS program also relied on secondary indicators of performance, including Mission Impaired Capability Awaiting Parts (MICAP).

The delivery standard for CONUS MICAP was 24 hours; however the program was able to achieve a MICAP of 14 hours. For OCONUS systems, the delivery standard was 96 hours, the program achieved a MICAP of 1 hour. With regard to repair turn around, the program averaged on site repairs in 1.2 days, well below the 5 day standard.

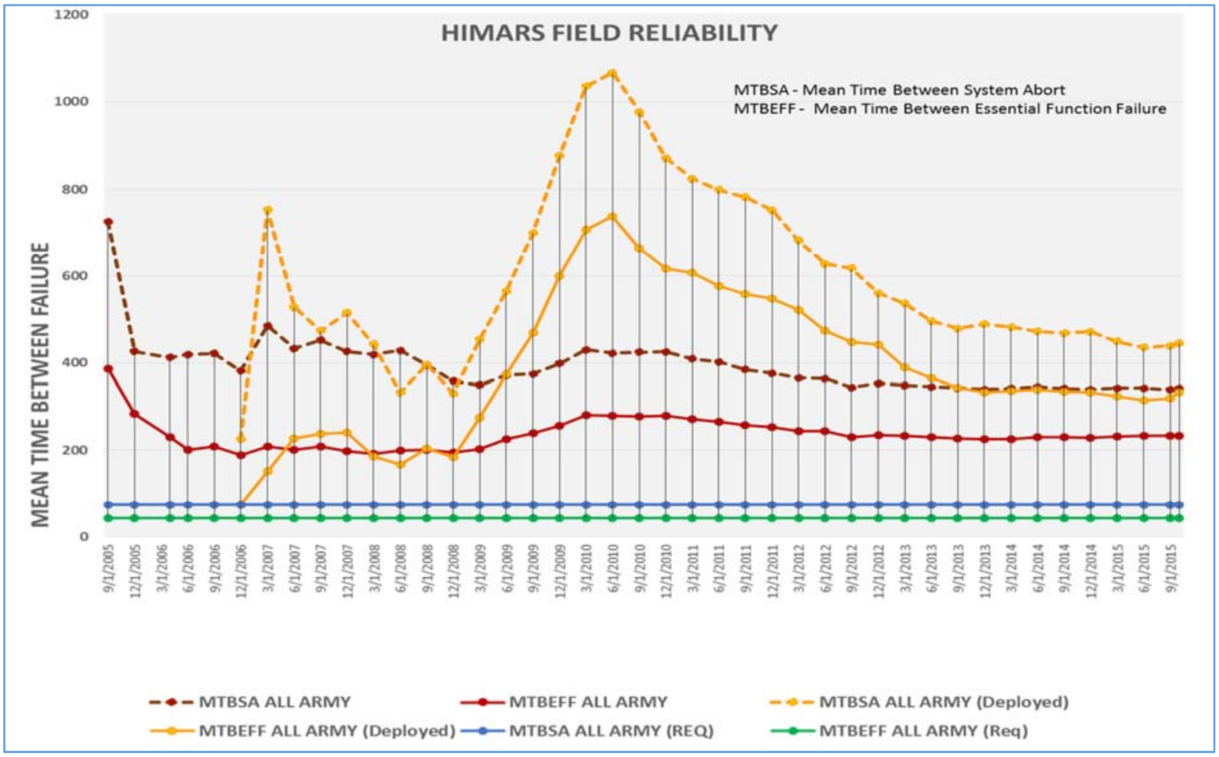


Figure 7. HIMARS Field Reliability

Note. The information in the graph came from Lockheed Martin, 2015)

The HIMARS program also tracks reliability through mandated field analysis reports, monitoring the mean time between system aborts (MTBSA) and mean time between essential function failures (MTBEFF). Figures 7 and 8 illustrate HIMARS units' reliability between 2005 and 2015. Note that reliability among deployed Army units, as measured by both MTBSA and MTBEFF, climbed significantly during 2009 and 2010, before stabilizing at levels that continue to exceed average reliability across all units. Note, also, that the peaks in reliability correspond with peaks in the number of operational hours for deployed units (i.e. 3rd quarter 2009 and 1st quarter 2010; See Figures 7 and 9).

HIMARS (FCS & LLM) LAUNCHER RELIABILITY (OVERALL)											
UNIT / BATTALION	IFCS & UFCS OPERATION TIME (HRS)	AVG. OPER. TIME PER LAUNCHER PER MONTH (HRS)	LLM MTBSA	LLM MTBEFF	FCS MTBSA	FCS MTBEFF	LLM & FCS MTBSA	LLM & FCS MTBEFF	IFCS LRU MTBF	UFCS LRU MTBF
US ARMY TOTAL	526,602	26.0	706	394	659	573	341	233	2,078	1,293
USMC TOTAL	377,002	99.0	2,005	1,062	879	765	611	445	1,560	2,094
US ARMY DEPLOYED	174,951	115.9	897	555	884	767	445	322	5,818	1,438
USMC DEPLOYED	278,067	545.1	5,149	2,897	1,487	1,330	1,154	912	3,233	2,681
REQUIREMENTS			188.3	116.5	118.5	67.5	72.7	42.7	293.0	293.0

Figure 8. HIMARS Sub-System Reliability Lockheed Martin, 2015
Note. LLM = Launcher Loader Module; UFCS = Universal Fire Control System; IFCS = Improved Fire Control System.

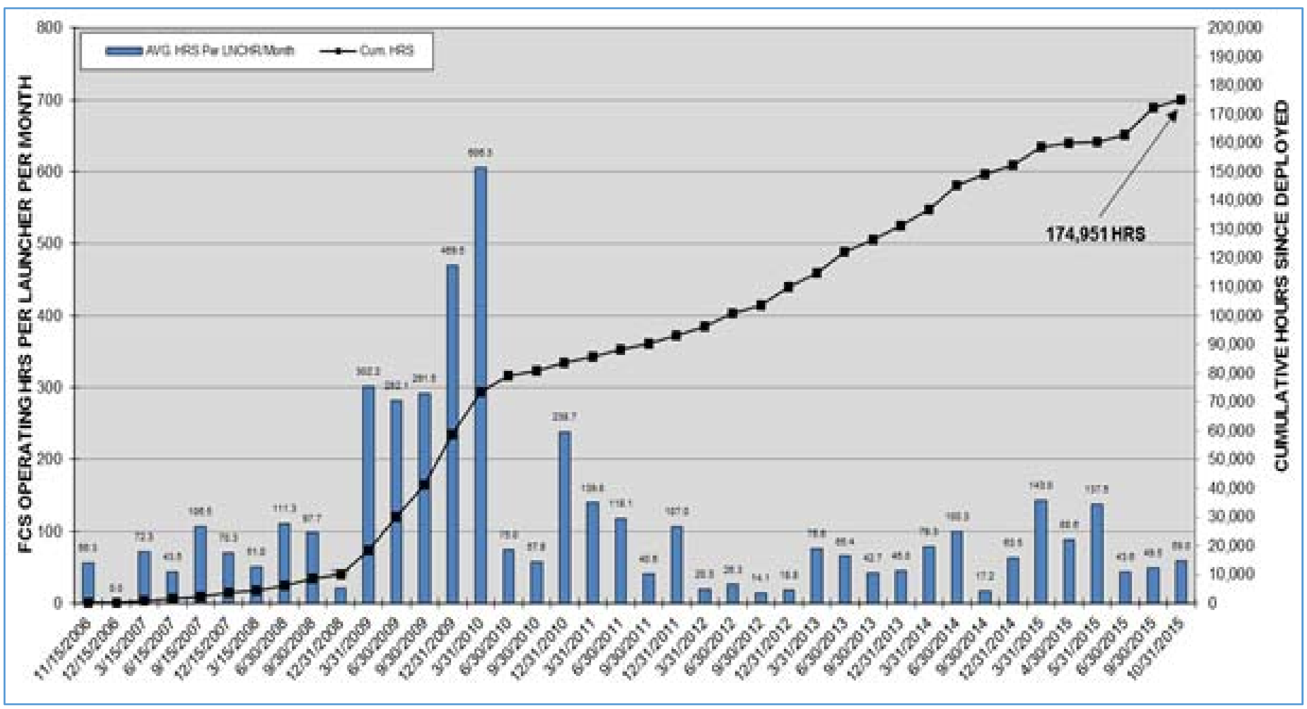


Figure 9. HIMARS Deployed Launcher Operational Hours (Lockheed Martin, 2015)

Despite the program's success, in 2015, the DoD transitioned inventory management from the contractor to the government in an effort to further reduce costs through more direct control. It remains to be seen whether the DoD’s decision will lead to lower costs and continued high performance.

AH-64 Apache

The AH-64 Apache was conceptualized as a high powered, tank killing, attack helicopter, capable of repelling conventional ground forces during a soviet invasion of Europe. Still an essential part of the Army’s fleet today, the primary mission of the Apache is to perform armed reconnaissance and conduct rear, close, and shaping missions, including deep precision strikes.

Since its inception, the Apache has accumulated over 3.9 million flight hours, with operational deployments during Desert Storm, Operation Iraqi Freedom, and Operation Enduring Freedom, and Operation Inherent Resolve in Iraq. Although the first AH-64 was delivered to the Army five years before the fall of the Berlin Wall, the Apache remains the Army’s primary and most advanced attack helicopter. Central to the Apache’s mission is the Target Acquisition and Designation Sight/Pilot Night Vision Sensor (TADS/PNVS) system, nicknamed the “eye of the Apache.”

A Brief History

The first generation of the TADS/PNVS system was fielded by the Army in 1983. The system, which comprises two sub-systems, enables Apache pilots to fly at low altitudes in total darkness and poor weather. The TADS/PNVS system also provides a capability that allows the co-pilot to identify and engage hostile targets (Yenne, 2005).

In 2003, Lockheed Martin was awarded a production contract for an upgraded, modernized version of TADS/PNVS. The M-TADS/PNVS, also known as the “Arrowhead,” is an “advanced electro-optical fire control system that AH-64D/E Apache helicopter pilots use for targeting and pilotage in day, night and/or adverse-weather missions” (Lockheed Martin, 2015). The updated version is projected to lower sustainment costs by 50% over the system’s expected 40-year life span (Lockheed Martin, 2015).

Prior to the initial TADS/PNVS PBL contract, the sustainment cost for the Apache’s sensors systems averaged $218 million per year. Product support functions were performed organically, with Lockheed Martin providing ‘repair and return’ services on a transactional basis (DoD, 2013).

Both the original TADS/PNVS and M-TADS are designed around the concept of the Line Replaceable Module (LRM). Technicians remove and replace faulty components directly, restoring the system to service quickly. The faulty component is sent for repair off-site. The LRM concept has been shown to reduce the cost, volume, and weight of spares holdings (Curtiss-Wright, 2016). The LRM design allowed technicians to remove and replace faulty equipment on the flight line. Intermediate-level maintenance of faulty components was performed at the division or corps level, while depot-level maintenance was performed either at the then Martin Marietta depot facility in Orlando, Florida, or at subcontractor facilities (Robbins & McIver, 1994).

A 1994 RAND report analyzing logistics support for the Army’s high-tech weapons found that the Army overstocked certain TADS/PNVS LRMs and understocked others. The report concluded that the inefficiencies in intermediate-level maintenance would have limited repair capability to only 25% of all received platforms during a large scale operation. The report attributed this limitation to the absence of prioritization mechanisms at critical repair facilities. In an effort to improve logistics efficiency, the DoD transitioned to a PBL in 2007.

Program Description

Since 2007, Lockheed Martin has provided sustainment for the AH-64 Apache Helicopter’s M-TADS/PNVS system through a series of three PBL contracts. The PBL program consists of three major functions: repair operations, logistics operations, and continuous improvement areas. Together, these functions established a system of continuous improvements supporting the Apache sensors and covered complete post-production supply chain management, including inventory management, maintenance, modifications, procurement, repairs, and spares planning of fielded systems. At present, the PBL supports over 670 aircraft in 27 battalions worldwide, including multiple forward operating bases (DoD, 2013).

Repairs are performed at five special repair activities (SRAs). The largest of these is the Letterkenny Army Depot Partnership in Pennsylvania, which repairs 29 of the 53 LRMs on the M-TADS system. The partnership employs 14 personnel (six government and eight Lockheed Martin) Other SRA locations are located in Arizona, Texas, Alabama, and Florida (Lockheed Martin, 2016).

The second function, Logistics operations, comprises U.S.-based depot support facilities and contractor supply support activities (CSSAs) located at domestic and overseas U.S. military installations and within close proximity to deployed Army units. The depot support facilities oversee the following functions: management of government-owned, contractor-managed assets; distribution of repair parts to SRAs; packing, handling, shipping, and transportation; and operation of storage facilities. The CSSAs consist primarily of forward-deployed Lockheed Martin-staffed support teams. In 2013, CSSAs had a presence in Afghanistan, Iraq, Germany, South Korea, and Kuwait (Lockheed Martin, 2016). The CSSAs serve as an information conduit between Army units and Lockheed Martin’s global support network. The CSSAs process repair orders, ensuring timely transportation of new parts from SRAs to deployed units.

Finally, the continuous improvement function of the PBL consists of a dedicated team of Lockheed professionals that work to improve reliability and maintainability as well as obsolescence management. The team relies on specialized IT tools, including an asset management system that “provides data necessary to identify and implement corrective actions and proactively push improvements into the field” (DoD, 2013). Among its numerous functions, the team investigates new failure trends; reviews reliability predictions to determine current and future needs; and develops low impact, and easy-to-implement solutions to recurring or emerging logistics or technical challenges.

PBL Strategy

The PBL has relied on firm fixed-price contracts that are tied to the number of flight hours. The program has established nine flight bands, each of which is designated by a maximum number of annual flight hours. The nine bands are separated by approximately 20,000 hours; band 1 has a maximum of 87,000 hours, band 10 a maximum of 240,000 (Lockheed Martin, 2016). Thus, the Army would pay the maximum annualized value of the contract during years in which Apache flies between 220,000 and 240,000 miles. This structure is ideally suited to heavily-deployed systems, such as the Apache, in that it provides the contractor with the traditional incentives associated with fixed-price contracts, translating to higher levels of innovation, reliability, and availability; at the same time, the contract is sufficiently flexible—the Army pays for actual usage—to support changes in operational tempo and accommodates multiple deployments (for instance, by establishing new deployed CSSA locations as needed).

The first four-year contract (one base year and three one-year options) was valued at approximately $380 million; in 2012, a similar follow-on contract valued at $375 million was awarded (Lockheed Martin, 2012). A third, five-year, PBL contract (one base year and four one-year options) was awarded in 2016. The contract was valued at $424 million, and represents a price reduction of 10% over the previous contract (Lockheed Martin, 2016).

Program performance is measured in terms of supply availability (SA). Lockheed Martin is contractually obligated to meet a minimum availability requirement of 85%. In other words, the requested part must be received by the requesting Army unit within the required timeframe 85% of the time. This timeframe varies depending on the type of part and the location of the requesting unit. There are three issue priority groups (IPG-1 is the highest priority; IPG-3 is the lowest) and two location categories, in-country and deployed. As with the H-60 Tip-to-Tail PBL, the program relies on this matrix to meet supply availability requirements. IPG-1/deployed have the shortest timeframe requirement, IPG-3/in-country have the longest (Lockheed Martin, 2016). As with the contract structure itself, the supply availability requirement injects flexibility into the program and aligns contractor priorities with those of the Army.

PBL Results

Under the initial contract, Lockheed successfully slashed sustainment costs for both sensor systems and improved supply availability primarily through improvements in supply chain and obsolescence management. Lockheed has lowered logistics and maintenance costs by leveraging data tracking for a number of health and maintenance indicators to improve demand forecasting, determining appropriate inventory levels, and by ensuring the optimal locations of supply activities.

Between 2007 and 2013, SA for MTADS/PNVS averaged 97%, well above the 85% requirement. Figure 9 illustrates annual availability by IPG between 2007 and 2011, followed by Monthly availability between January, 2012 and May, 2013. Notably, a high level of availability was maintained between 2011 and 2013 when Apache reached its peak OPTEMPO of over 200,000 flying hours per year. In 2012, 96,000 hours were accumulated in Afghanistan alone. The other 115,000 hours were accumulated at locations in Kuwait, Germany, Korea, and CONUS locations (Lockheed Martin, 2016). The program has prioritized the availability of deployed units, which between 2012 and 2013, averaged 99%.

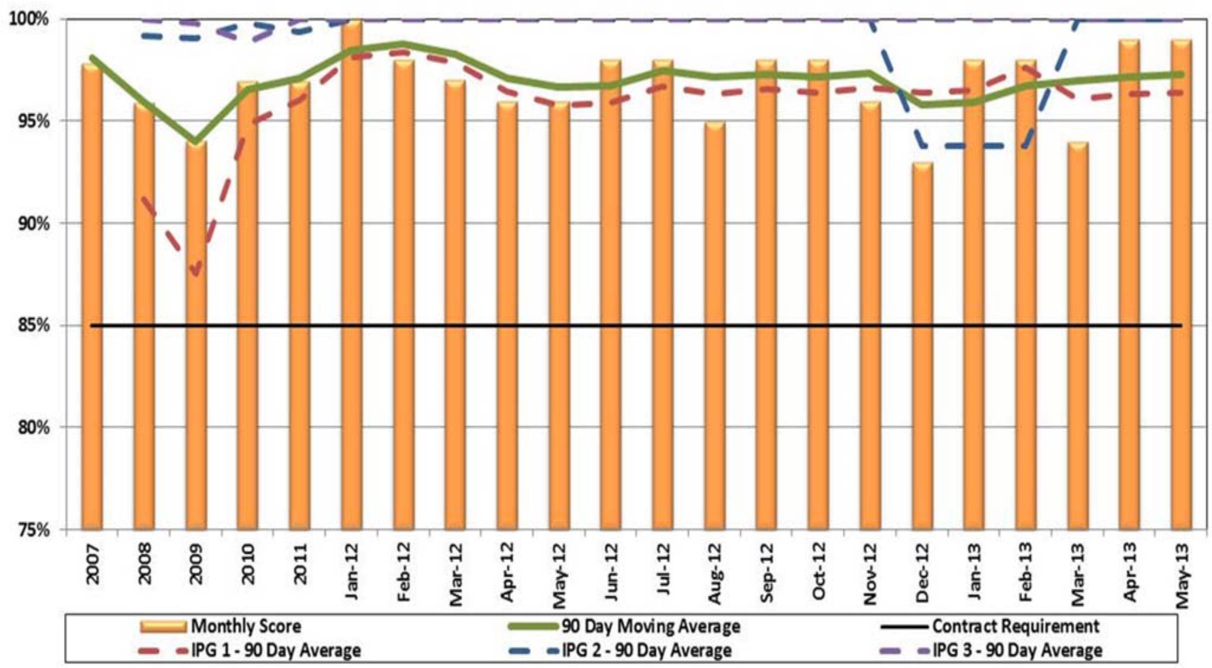


Figure 10. M-TADS/PNVS Parts Availability (Breter, 2013)

Lockheed professionals working within the continuous improvement function have developed numerous solutions that have increased mean time between system failures (MTBF) by 70% compared to the pre-PBL period. Often "simple fixes" such as redesigned screws that strip less easily; a protective guard that prevents damage to exposed machinery; and improved air flow gaskets have all served to drastically improve reliability, durability, and overall performance. In addition, Lockheed has been successful in drastically increase the annual retrograde rate—i.e. the rate at which repairable parts are transported to depots for repair, in preparation for those parts to be placed back into the supply chain—reducing the number of spares and the overall logistics footprint required to store and maintain them (See Figure 11).

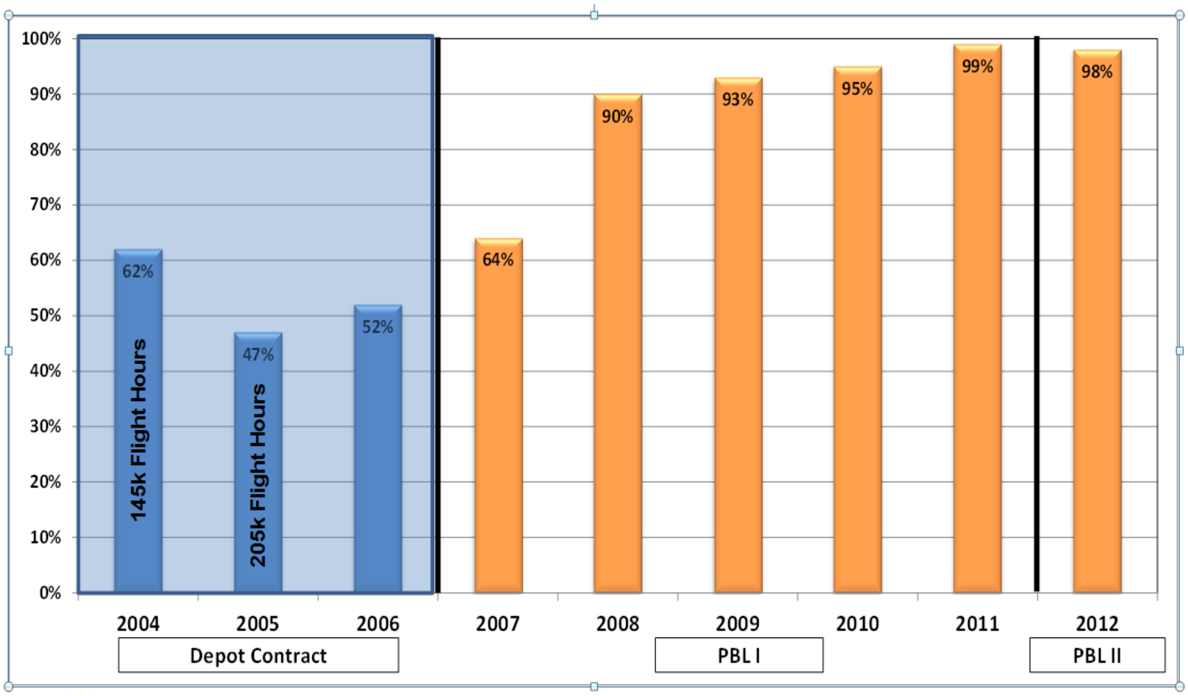


Figure 11. M-TADS/PNVS Retrogrades by Year (Breter, 2013)

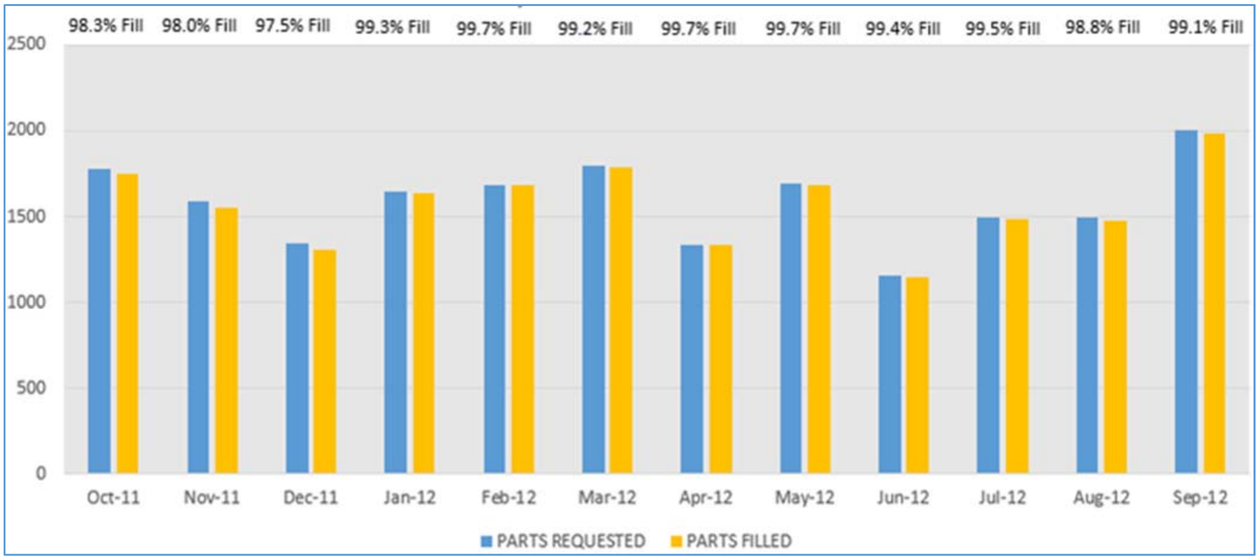


Figure 12. M-TADS/PNVS Depot Repair Parts Availability (Breter, 2013))

The program also exceeded 99% availability for depot repair parts (See Figure 12). The PBL contract has been credited with improving fleet readiness, reducing average flying hour cost and reducing the Army's long-term inventory investment. Over the course of the initial PBL contract, depot-level repairable costs were reduced by 18%, supply inventory replenishment costs were reduced by 40%, and mean-time between maintenance actions reduced by 9.6% (OSD, 2012).

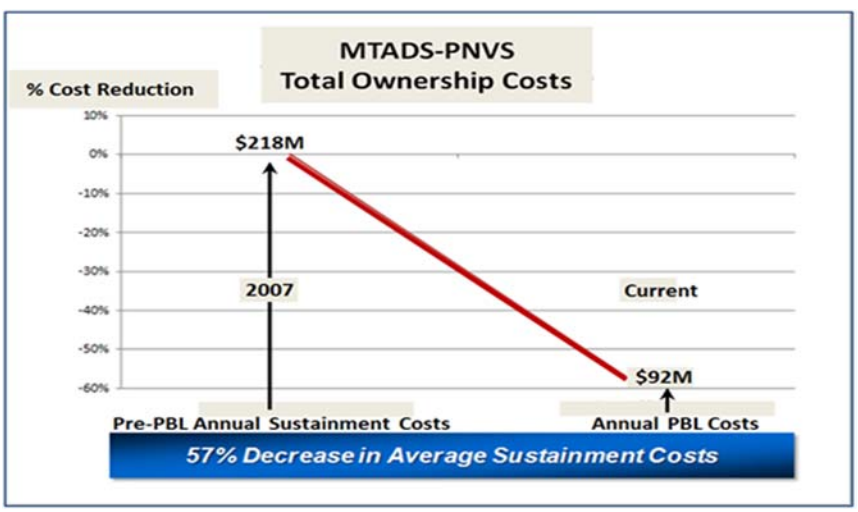


Figure 13. MTADS/PNVS Total Ownership Costs (Breter, 2013)

As mentioned previously, annual sustainment costs prior to the implementation of PBL totaled $218 million per year. In 2013, costs totaled $92 million, a drop of 58% (See figure 13). Other accomplishments include the mitigation of 759 obsolescence and diminishing manufacturing cases since 2007 resulting in $104.2 million in cost avoidance, the reduction of the maintenance support footprint, and a decrease of over 1,000 maintenance man hours per year through increased materiel reliability (OSD, 2012). These efficiencies enabled the government to negotiate a price reduction of approximately 10 percent, reflected in the most recent contract awarded in 2016.

Stryker

The U.S. Army's first new vehicle since the early 1990s, the M1126 Stryker is a rapidly-deployable wheeled armored vehicle. Stryker successfully combines resiliency, mobility, and versatility, creating the ideal combat vehicle and quickly becoming an essential tool for the United States Armed Forces (Military.com, 2015). Created to meet the need for a combat capable and rapidly deployable armored vehicle, the Stryker brigade has successfully implemented new sustainment concepts to reduce logistics requirements and increase performance (GPO, 2006).

These concepts, including minimizing the number of personnel and spare parts within the brigade and "reaching back to assets outside the brigade for support", have made the Stryker PBL program one of the most successful in the Army's history (GPO, 2006). Furthermore, its lightweight design permits for easy transport by C-130 aircraft, allowing for its use in previously unreachable areas and making it a desirable commodity in combat situations. In fact, Stryker can be deployed "anywhere in the world within 96 hours". The vehicle combines speed and agility, with state of the art levels of protection. It is able to travel at speeds up to 62 mph on highways with a range of 312 miles on 53 gallons of fuel and its integrated armor package effectively protects soldiers against IEDs and RPGs as well as a slew of other infantry weaponry, adding to its appeal in any combat situation (Coryell, 2007).

A Brief History

As top Army officials became increasingly frustrated with the attributes of existing combat vehicles—many of which were either too heavy to be deployed efficiently or too light to be effective in combat—the Army began its search for a new armored vehicle for its fleet. To make matters more pressing, US troops in Iraq and Afghanistan were facing unprecedented threats from improvised explosive devices (IEDs), heightening the need for a new armored vehicle. The Stryker vehicle was among the fastest acquisitions of a major weapons system in U.S. history.

The heavily armored vehicle allows the team to successfully maneuver in close and urban terrain, provide protection in open terrain and transport infantry quickly to critical battlefield positions (Army-Technology, 2015). Currently, there are two variants of the Stryker vehicle – the Infantry Carrier Vehicle, or ICV – which comes in eight variations, and the Mobile Gun System, MGS (Military.com, 2015). The ICV, which requires a two-man crew (driver and vehicle commander), is capable of carrying nine infantry soldiers and their equipment, and comes in eight configurations, each with combat service and combat support roles. Those configurations include a Commander’s Vehicle (CV), Reconnaissance Vehicle (RV), Fire Support Vehicle (FSV), Mortar Carrier (MC), Anti-Tank Guided Missile vehicle (ATGM), Engineer Squad Vehicle (ESV), Medical Evacuation Vehicle (MEV), and Nuclear, Biological, and Chemical Reconnaissance Vehicle (NBCRV).

Program Description

In November of 2000, General Dynamics Land Systems (GDLS) was awarded a $4 billion contract to supply the Army with 2,131 vehicles over six years (Global Security, 2015). Less than two years later, in May 2002, GDLS was awarded a contract for the Stryker vehicles with an option for Interim Contractor Logistics Support (ICLS)—which would fall under a Cost Plus Fixed Fee portion of the larger contract.

The program’s initial focus was centered on reducing the number of personnel and spare parts needed within each Stryker Brigade Combat Team (SBCT) in an effort to reduce costs. In

2005, GDLS relied on 45 contractors embedded within combat teams to provide maintenance and sustainment for all SBCTs (GAO, 2006). To achieve this goal, the Stryker vehicle contract relied on a contract for contractor logistics support (CLS), wherein virtually all sustainment activities and the associated logistics capability are carried out by contractors. The Stryker PBL contract was fairly straightforward—under the PBL arrangement, the contractor was responsible for ordering spare parts, managing a spare parts warehouse, worldwide distribution of repair parts, and completing maintenance services on Stryker wheeled combat vehicles (Coryell, 2007). Contractors filled a variety of roles including vehicle mechanics, armament repairers, and automated logistics specialists.

GDLS was responsible for all sustainment efforts at CONUS and OCONUS locations. GDLS implemented a number of innovative sustainment concepts, including

- self-sustained operations for 72 hours;
- echelons above Brigade (EAB) reliant beyond 72 hours;
- heavy use of Unit Basic Loads (UBL);
- on-system repair enablers;
- reliance on whole item CL VII/ Operational Readiness Float (ORF) replacement;
- scheduled pulse of supply/services distribution every other day (not daily); and
- logistics surge capability (Coryell, 2007)

In addition to the maintenance, repairs, and spare parts, GDLS is also responsible for providing storage facilities for many Stryker vehicles, and completely overhauling and refurbishing damaged vehicles all while managing the Stryker-specific supply chain (Denizer, 2007).

Given the crucial role SBCTs have played in American military efforts, especially in Iraq; the vehicles limited self-sustainment capabilities; and the number of miles traversed over the course of the conflict—5.6 million miles during its first two deployments, 800 percent higher than anticipated usage—the Stryker program was unique in the level of contractor support that was required (Denizer, 2007).

PBL Strategy

Awarded to General Dynamics Land Systems in 2000, the initial PBL for the Stryker vehicle fell under a Cost Plus Fixed-Fee (CPFF) portion of a larger contract for vehicle manufacture and delivery. The CPFF covered "all fielded vehicles in garrison or deployed" for a five year period (Coryell, 2007). Under the agreement, GDLS would produce and repair or maintain vehicles at four primary locations in Alabama, Alaska, Ontario, and the United Kingdom (Denizer, 2007).

The CPFF was chosen to provide maximum flexibility to meet rapidly-evolving conditions while allowing Army officials to gauge the costs associated with different levels of performance so that a Firm Fixed-Price (FFP) contract could be used at a later point (Coryell, 2007). The initial contract specified a single metric, an operational readiness rate (ORR). Vehicles were expected to meet a 98% ORR during fielding and training exercises at least a 90% ORR for deployed vehicles in combat environments.

GDLS would go on to win two follow-on PBL contracts, in 2007 and 2012, valued at $1.5 billion and $2.5 billion respectively, which would extend sustainment and support for the growing Stryker fleet. In 2007, some 1,500 vehicles have been fields; by 2012, this number had risen to close to 2,500 (DoD IG, 2012).

PBL Results

For the first two Stryker brigades that deployed to Iraq, Army officials reported operational readiness rates averaging 96% from October 2003 through September 2005 (GAO, 2006). In addition, the Army consistently noted that contractors were providing impressive levels of support and according to a 2006 GAO report, more knowledgeable and efficient than their military counterparts with regard to the specifics of the Stryker vehicles (GAO, 2006). The program's use of contractor personnel for sustainment efforts allowed soldiers on the ground to participate in extra trainings and perform other necessary, military specific, roles (GAO, 2006). Pre-existing relationships between soldiers within SBCT and deployed contractors also created a successful and effective work environment overseas.

From a cost perspective, however, contract performance is less clear. In 2012, The DoD Inspector General asserted that the follow-on contract's continued use of a sole metric (readiness) in combination with a high-ceiling, cost-plus contract unduly incentivized the contractor to accumulate significant excess inventory valued at $335.9 million (DoD IG, 2012). The Army responded that the excess inventory could be attributed, in part, to contractor improvements in reliability, and that the spare parts would be used eventually, albeit at a slower pace than anticipated (DoD IG, 2012).

Given the Army's heavy reliance on Stryker during the Iraq War, changing operational tempos, and the lack of historical cost data, the use of a cost-plus fixed fee contract (as opposed to a fixed-price contract) was well-founded. However, it appears that the Army could have implemented better cost controls, perhaps by tying the fixed fee to an agreed-upon cost-per-mile metric. As indicated in the previous section, the DAU lists cost-per-unit metrics as essential indicators of PBL performance.

In November of 2005, citing a need for increased flexibility in different combat environments, and DoD-wide concerns over the use of contractors in combat environments, the Army determined that soldiers, as opposed to contractors, would perform unscheduled maintenance for all Stryker vehicles (GAO, 2006). The Army's plan called for replacing 45 Stryker vehicle maintenance contractors with 71 soldiers. This transition relied on the Army's ability to annually recruit or retain 497 additional soldiers with specific military specialties to support all seven Stryker brigades (GAO, 2006). The GAO questioned the Army's plan, asserting, ironically, that the larger logistics footprint could negatively impact Stryker's deployment flexibility. In 2006, the Army began the transition, which, at present, is still underway.

IV. Findings, Recommendations, and Conclusion

Figure 14 provides summary statistics for the four PBL programs.

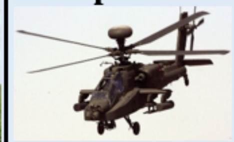
	H-60 	HIMARS 	Apache 	Stryker 
PBL Initiation	2003	2004	2007	2002
Deployed in Theater	Iraq	Iraq, Afghanistan & Syria	Iraq & Afghanistan	Iraq & Afghanistan
Level of Support	Parts & Components	Sub-System	Sub-System	System
Contract Type	FFP	CPFF – *OCONUS* FFP – *CONUS*	FFP	CPFF
Cost Per Unit Measure?	**Yes** *Flight Hour Bands*	**Yes** *OPTEMPO Categories*	**Yes** *Flight Hour Bands*	**No**
Reduced Annual Sustainment Costs?	**Yes** *$8.2M vs. pre-PBL*	**Yes** *Estimated $100M, BCA*	**Yes** *$126M vs. pre-PBL*	**No Data**
Exceeded Performance Requirement?	**Yes** *Requirement: 80%* *Achievement: 98%* *(Availability)*	**Yes** *Requirement: 92%* *Achievement: 99%+* *(Readiness)*	**Yes** *Requirement: 85%* *Achievement: 97%* *(Availability)*	**Yes** *Requirement: 90%* *Achievement:96%* *(Readiness)*
Exceeded Reliability Requirement?	**N/A** *No Formal Requirement*	**Yes** *Avg. 860%* *(FCS-LRU)* *Above Requirement*	**Yes** 70% *Above Requirement*	**N/A** *No Formal Requirement*
Currently Operating as PBL?	**Yes**	**Yes** *DoD controls some supply chain functions*	**Yes**	**Yes**

Figure 14. Case Study Results

Findings

Based on our examination of the PBL mechanism, its proven applications, and four PBL-supported systems, we provide our findings:

1. PBL-supported systems operating in stressful environments are capable of meeting or exceeding performance requirements, contributing to mission success.

In all four cases, the PBL programs met or exceeded performance requirements in operational availability and readiness. In light of new and emerging threats, a program's proven ability to consistently meet high performance standards in excess of 90, 95, or 99% availability/readiness cannot be overstated.

2. PBL contractors have the proven ability to support weapons systems operating in stressful environments.

Over the last several years, there has been unprecedented contractor participation (in numerous roles) in the conflicts in Iraq and Afghanistan, with some voicing concern over the presence of "contractors on the battlefield." Needless to say, a line must be drawn between contractor support and direct participation in combat operations, though this was not an issue in the four cases under examination. Rather, these cases demonstrated that PBL contractors are willing and able to perform a critical supporting role, even in stressful combat environments.

3. PBL provides sufficient flexibility and capacity to adapt to changing operational tempos.

The four cases suggest that PBL programs are adaptable and scalable, provided that they are structured appropriately. PBLs relying on cost-plus contracts provide inherent flexibility (to the government and the contractor) in the face of uncertainty, both technical and operational. Fixed-price PBLs also provide flexibility, especially when price is tied to operational tempo (number of flight hours, miles driven).

4. All support contracts, including PBLs operating in theater, should apply stringent cost controls.

Owing in part to demonstrated success of PBL in meeting performance requirements, it may be that less attention is paid to contract specifics beyond readiness/availability metrics. Carefully-considered contract ceilings, cost-per-unit usage rates, and logistics footprint constraints should be included in cost-plus contracts. Without these features, contractors may be incentivized to accrue surplus inventory beyond what is necessary to meet the performance requirement.

Recommendations

Overall, throughout our research the vast benefits of performance based logistics, particularly in combat environments, have become increasingly clear. Based on these findings, we provide the following recommendations to the DoD:

1. Promote the use of PBL as a proven support strategy for weapons systems.
PBLs perform better than traditional support mechanisms, even in stressful environments. The DoD should renew its commitment to the expansion of PBL in order to improve weapons systems operation and reduce costs.

2. Ensure proper alignment of government objectives with provider incentives.
Critics suggest, perhaps rightly, that PBL arrangements can be more challenging to develop and manage than other contract types. Just as an appropriate PBL program structure aligns the incentives of the customer (the government) and the support provider, leading to a win-win scenario, an inappropriate structure can create perverse incentives, and result in undesired or unintended consequences.

3. Structure PBL contracts appropriately
In environments characterized by relatively low levels of uncertainty, both operational and technical, alignment of contractor and government objectives is optimized under fixed-price PBL contracts. These arrangements promote greater cost-reduction incentives, higher levels of innovation, and enhanced reliability. Often, these contacts rely on only one or two performance metrics, which ensures transparency and accountability. However, in stressful, unpredictable environments, cost-plus PBL contracts are often more suitable in that they provide greater flexibility to meet mission objectives. In these circumstances, however, programs may need to employ additional metrics beyond reliability and

availability, including cost-per-unit usage rates and logistics footprint constraints, in order to strike the optimal balance between required availability and cost.

4. Avoid distortions to the PBL paradigm

From a theoretical standpoint, the power of PBL lies in affording the provider the discretion and flexibility to select the optimal mix of inventory levels, maintenance activities, and technology upgrades in order to meet performance requirements. Shifting one or more of these functions to the government customer distorts the PBL paradigm and may lead to reductions in performance, innovation, and cost savings.

Conclusion

As defense budgets continue to shrink, and operations and maintenance costs for weapon systems continue to rise, the DoD must heighten its focus on affordability and efficiency when it comes to new and existing weapon programs. With its vast array of benefits, performance based logistics has the potential to dramatically reduce the costs of procuring and sustaining weapon systems, while incentivizing higher levels of performance. As we continue to face new and evolving global threats, the demand for superior and highly reliable technology is now more crucial than ever. Although its benefits have been consistently proven throughout the years, PBL is not being aggressively pursed throughout the DoD.

The case studies suggest that deployed units sustained through PBL programs are capable of exceeding performance and cost requirements, often outperforming weapons systems in garrison. Summary statistics for these PBL programs were provided in Figure 14.

The systems we examined are among the most deployed PBL-supported systems; they also represent a wide diversity with regard to contract type, terms, and length. Furthermore, combat vehicles and helicopters are known to require the highest levels of repair and reconditioning, making their performance all the more noteworthy.

Ultimately, we found little to justify the notion that PBL programs, when properly-implemented, have trouble performing in stressful environments. Our findings support the notion that the DoD would be well advised to expand the use of PBL for the sustainment of weapon systems.

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