Cracking Open the 'Black Box' of Product Technical Support Contracts

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Abstract

When major weapon systems enter the production phase of their lifecycle, a significant amount of support is required to address an array of technical issues. For the Army's ground combat systems, such technical services are procured using Product Technical Support contracts that require tens of millions of dollars annually. When estimating funding requirements for ground combat vehicle Product Technical Support contracts, it can be difficult to predict what specific projects and technical challenges a program will face in the future. Estimating Product Technical Support costs is further complicated by the fact that no comprehensive data analysis has ever been done across multiple Army ground combat programs.

The authors of this paper collected and examined multiple Product Technical Support contracts and thousands of associated data sources for four such programs. The work scope for the four programs analyzed represents over a billion dollars expended across a 14 year period. This paper leverages that analysis to explore the nature of Product Technical Support work and categorize it into meaningful ‘service categories’. The goal of this paper is to make sense of the dizzying complexity of Product Technical Support work by explaining it in logical service categories that occur across programs and how the information presented herewith can be utilized by the Army to help predict future Product Technical Support contract requirements as it modernizes its fleet of ground combat vehicles.

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Introduction

In surveying the landscape of the United States Army Acquisitions, often times it is production contracts that draw the most attention, interest, and scrutiny based on the dollar amounts awarded and the direct mission impact of the end items. From one perspective, this makes sense – after all, production contracts represent the procurement of the hardware and weapon systems utilized by the Army and the Department of Defense (DoD). However, from a funding perspective, non-production contracts make up a far larger portion in terms of how the Army budgets and spends money, including the awarding of Product Technical Support (PTS) contracts.

Figure 1 represents the distribution of DoD spending in Fiscal Year (FY) 2020 across five categories: Research, Development Test & Evaluation (RDT&E), Procurement, Military Construction and Family Housing, Military Personnel, and Operations and Maintenance (O&M):

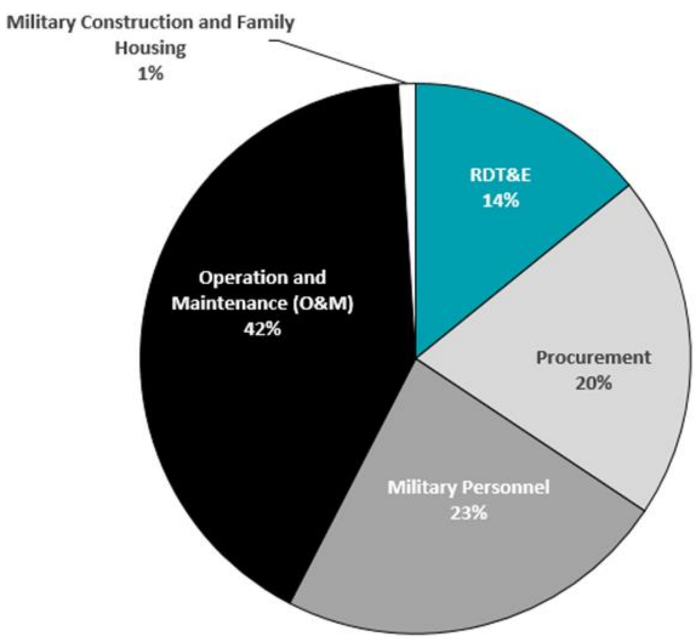

Figure 1: DoD Spending by Category in FY 2020 (% of Total DoD Outlays)[1]

The procurement slice of the pie presented in Figure 1 includes the myriad of production contracts that DoD awards to industry annually. The three primary U.S. military branches (Army, Air Force, Navy) acquire a wide range of commodity types via these contracts, specifically the following commodities identified in Military Standard 881E[2] (MIL-STD 881E):

- Ground Vehicle Systems
- Aircraft Systems
- Electronics/Avionics/Generic Systems
- Sea Systems
- Missile/Ordinance Systems
- Strategic Missile Systems
- Space Systems
- Unmanned Maritime Systems
- Launch Vehicle Systems

These contracts garner significant attention and scrutiny because they are costly and critical to equipping our warfighters with the end items (i.e., weapons and automated systems hardware, software, etc.) to achieve their varied, critical missions.

Despite their cost and importance, these contracts represent only a subset of the procurement slice from Figure 1 and only part of the cost picture related to ensuring our warfighters are properly equipped. Additionally, and as will be the primary focus of this paper, the Army and the other services award other contracts for a wide range of costly services that are essential for cost analysts to understand in preparing estimates that support informed budget and contracting decision making.

These Product Technical Support (PTS) contracts cover a variety of important costs associated with major defense system program lifecycles and are financed with Procurement, as well as RDT&E and O&M funding. In the case of Army PTS contracts, the costs include, but are not limited to: Contractor Logistics Support (CLS), Technical Manual Updates, Engineering Modifications, Software Maintenance, as well as several others cost elements discussed throughout this paper. Table 1 presents several PTS contracts that have been awarded by the Army in recent years.

Weapon System(s)	Year Awarded	Base Contract Value	Current Contract Value	Contract #	Source
Abrams	FY07	$56M	$1.1B	W56HZV-07-C-0046	www.usaspending.gov
Bradley	FY15	$14M	$604.4M	W56HZV-15-C-0099	www.usaspending.gov
Abrams	FY17	$12M	$862.9M	W56HZV-17-C-0067	www.usaspending.gov
AMPV/ M113	FY21	$5.6M	$5.6M	W56HZV-21-F-0276	www.usaspending.gov

Table 1: Recent Army PTS Contracts

As indicated by the dollar amounts associated with the contracts listed, the magnitude of PTS contracts represent a significant cost within the program lifecycle for ground vehicle systems. However, Army PTS contracts are often structured in a way that makes it difficult to determine the exact distribution of total PTS contract costs to specific cost elements defined in the 2020 Army Cost Analysis Manual (CAM)[3]. The CAM and the Cost Element Structure (CES) presented within it are a critical aspect of Army cost estimates in that all Lifecycle Cost Estimates (LCCEs) developed for Army programs must adhere to the CES.

The Level I and Level II elements defined within Army CES are listed in Table 2:

CES #	COST ELEMENT
1.0	**RDT&E-FUNDED ELEMENTS**
1.01	DEVELOPMENT ENGINEERING
1.02	PRODUCIBILITY ENGINEERING AND PLANNING (PEP)
1.03	DEVELOPMENT TOOLING
1.04	PROTOTYPE MANUFACTURING
1.05	SYSTEMS ENGINEERING/PROGRAM MGMT (SE/PM)
1.06	SYSTEMS TEST AND EVALUATION
1.07	TRAINING
1.08	DATA
1.09	SUPPORT EQUIPMENT
1.10	DEVELOPMENT FACILITIES
1.11	OTHER RDT&E
CES #	**COST ELEMENT**
2.0	**PROCUREMENT ELEMENTS**
2.01	NON-RECURRING PRODUCTION
2.02	RECURRING PRODUCTION
2.03	SE/PM
2.04	SYSTEMS TEST AND EVALUATION
2.05	TRAINING
2.06	DATA
2.07	SUPPORT EQUIPMENT
2.08	OPERATIONAL/SITE ACTIVATION
2.09	FIELDING
2.10	WAR RESERVE AMMUNITION/MISSILES
2.11	SOFTWARE MAINTENANCE
2.12	TECHNICAL REFRESH
2.13	HELP DESK
2.14	OTHER PROCUREMENT

CES #	COST ELEMENT
3.0	**ACQUISITION OPERATIONS AND MAINTENANCE (O&M)**
3.01	SE/PM GOVERNMENT RDT&E EFFORTS
3.02	SE/PM GOVERNMENT PROCUREMENT EFFORTS
3.03	OTHER ACQUISITION O&M
4.0	**MILCON-FUNDED ELEMENTS**
4.01	DEVELOPMENT CONSTRUCTION
4.02	PRODUCTION CONSTRUCTION
4.03	OPERATIONAL/SITE ACTIVATION CONSTRUCTION
4.04	OTHER MILCON
5.0	**OPERATING AND SUPPORT (O&S) ELEMENTS**
5.01	UNIT-LEVEL MANPOWER
5.02	UNIT OPERATIONS
5.03	MAINTENANCE
5.04	SUSTAINING SUPPORT
5.05	CONTINUING SYSTEM IMPROVEMENTS
5.06	INDIRECT SUPPORT
6.0	**DEMILITARIZATION**

Table 2: Army Cost Element Structure (CES) (March 2020)

It is worth noting that '*Product Technical Support*' is not specifically called out as a Level II cost element. In fact, further inspection of Levels III and IV of the CES will yield no results for the term '*Product Technical Support*' or any other synonymous terminology (various alternative terms for PTS contracts are discussed below). This finding leads to a question that often gets asked within Army cost estimating circles:

"If 'Product Technical Support' is not an Army-defined cost element, then what type of work is being awarded with PTS contracts?"

The answer to this question is critical in that it not only helps identify how funding across multiple appropriations is utilized to fund work on PTS contracts, but also is critical to assisting the Army develop PTS budgets for future systems.

As the Army continues to modernize its fleet through implementation of the Next Generation Combat Vehicle (NGCV) program[4], several legacy systems nearing the end of their useful lives will likely be replaced with new systems designed to prepare the Army for future combat operations. These new systems include the Armored Multi-Purpose Vehicle (AMPV), Mobile Protected Firepower (MPF), Optionally Manned Fighting Vehicle (OMFV), the Robotic Combat Vehicle (RCV) and Next Generation Main Battle Tank[4]. The prototype and production contracts awarded for these systems will (quite deservedly) receive a great deal of attention, as they represent tens of billions of dollars in future business for the winning Original Equipment Manufacturers (OEMs) and a significant upgrade to the Army warfighters needs, mission and objectives. However, the technical support associated with maintaining, upgrading and enhancing these systems throughout their economic useful life (EUL) will be every bit as important from a mission perspective as acquisition of the systems and, realistically, several times as costly.

The primary objective of this paper is to perform a deep dive on some of the Army's legacy weapon systems PTS contracts in order to provide a detailed look at how costs incurred on PTS contracts are distributed across the CES by both appropriation and individual cost elements. However, additional recommendations and considerations for budgeting and contracting for PTS contracts on future ground vehicle systems will be addressed throughout.

Product Technical Support Contract Overview

What is a Product Technical Support Contract?

Before conducting an analysis of how PTS contracts are split up by cost element, or even by appropriation, another important question must be addressed:

"What exactly is a Product Technical Support Contract?"

Unfortunately, these types of contracts are not universally defined throughout the DoD or even within the individual services, including the Army. For example, the Federal Acquisition

Regulation (FAR) provides detailed definitions of various types of contracts including Fixed Priced, Cost Reimbursement and Incentive contracts. However, a quick search through FAR Part 16, Types of Contracts, for PTS contracts yields zero results. Alternative terms for PTS contracts often used within Army Acquisition include but are not limited to System Technical Support (STS), Engineering Services and Technical Support contracts. Again, searching the FAR for any of these terms and a definition of these types of contracts will return zero results. For the purpose of this paper, a PTS contract is defined as follows:

"A contract awarded by a Service acquisition program management office that provides hardware and software technical support, maintenance and, in some cases, repair parts for selected military weapon systems."

When comparing the list of cost elements from Table 2 to the definition derived above, it would seem that a primary purpose of a PTS contract is to serve as a sort of 'catch-all' for several different types of services and support. As the research and analysis presented throughout this paper will indicate, 'catch-all' is a very good way to describe the intent of a PTS contract in that work aligned with several of the RDT&E, Procurement and O&M funded cost elements are indeed funded and executed using PTS contracts.

The Anatomy of Product Technical Support Contracts

The previous section has helped define PTS contracts as a mechanism utilized by the Army when it is looking to accomplish a broad spectrum of tasks, deliverables, or services in support of a major weapon system. However, and as the analysis detailed in this paper will show, the Army may not necessarily know how much of this support it will need or when it will need it. Once again referencing FAR Part 16, Indefinite Delivery, Indefinite Quantity (IDIQ) contracts are ideal contracting mechanisms for acquiring services when there is a known need for a defined period of time, but the level of effort and/or time-phasing of the effort is uncertain. It is then no coincidence that PTS contracts are almost exclusively IDIQ contracts. However, once an IDIQ contract has been identified as the preferred contracting mechanism for PTS work, several decisions must be made in regard to how the contract will be structured. For instance, if a vendor is awarded an IDIQ PTS contract, will the Government simply award that vendor money as the need for a service arises? The answer to that question is emphatically 'no'. Several other considerations and decisions must be made in regard to an IDIQ PTS contract before execution can begin.

Below is a list of separate components that make up an IDIQ PTS contract:

1. Contract Line Item Number (CLIN): CLINs are partitions of contracts that break the contract down by the products or, in the case of PTS contracts, services being procured. CLINs help identify the supplies or services to be acquired as separately identified line items on a contract and provide for accounting traceability.
2. Sub-CLIN (SLIN): SLINs serve the same purpose as the CLIN; however, several SLINs typically roll up to a single CLIN. SLINs break down components of a product or service being procured into sub-components that, when combined, equate to the product or service at the CLIN level.
3. Work Directives: Work Directives are contractual instruments that capture detailed tasks, typically with a shorter period of performance relative to CLINs or the PTS contract itself, having specific objectives, goals or scope relative to work that is to be performed or materials that are to be provided.

Procuring Contracting Officers (PCOs) will work with the weapon system Program Offices and the OEMs to utilize these contractual components and structure the PTS contract in a manner that makes sense from a hierarchical perspective in terms of accomplishing tasks and objectives in support of the weapon system. In the next section, the data collection and data discovery conducted for this study will further detail where specific data and details reside within the contract, CLIN, SLINs and Work Directives.

Data Collection

Data Sources

Before conducting analysis on PTS contracts for individual weapon systems, specific data of interest in the contracts and other supplemental documents was identified. This data discovery phase consists of reviewing the contractual documents, as they are the authoritative source for government acquisition. Analyzing the native contracts themselves is an immensely beneficial exercise that offers a glimpse into the composition of PTS contracts. The overall contract value can be broken out into specific fiscal year and color of money expenditures through deduction of the Line of Accounting (LOA). However, mapping an expenditure to the Army CES is challenging due to the often-vague scope of work specified in the CLIN or SLIN description. For example, a sample CLIN pulled from one of the four contracts analyzed for this research was labelled as follows:

"*FY08 Program 1 PTS – Services Priced*"

Based on this descriptor, it is next to impossible to determine the exact scope of work as well as the applicable cost element from the CES. All that can be determined about this work is that it is funded with Fiscal Year 2008 funding, the work is associated with Program 1 and it is associated with a PTS contract. Fortunately, this issue can be greatly reduced and, more often than not, resolved by utilizing another data source related to PTS contracts, specifically, work directives.

Building on the definition offered in the previous section, work directives can be defined as an effort used to affect a procurement action within a procurement activity. Therefore, work directives pre-date the contract action that initializes the scope of work. This process answers the question as to why CLIN descriptions often lack detail. However, it is important to note that not all work directives are put on contract. Interestingly, the US Army Armament Command analyzed the average cost of creating a work directive due to the fact that the work directives can be cancelled at any time in the planning process.[5] Nonetheless, the work directives that are put on contract are essential to understanding the full context of work performed within a PTS contract.

With a clear path forward to understanding the actual work better, the next effort should be centered on collection of the actual costs incurred for the work. While the contract provides the overall price ceiling and in some cases a breakout of those prices, it does not convey actual costs incurred. Direct costs or inputs such as labor hours, direct material and travel can only be reported after they have been incurred. While a contract's price should be somewhat representative of eventual costs, actual costs are always preferred when comparing datasets or building estimates. In short, actual costs provide a comprehensive, authoritative view into detailed costs associated with the work performed, i.e., what actually happened vice what was expected to happen.

While other data sources (Federal Procurement Data System, USASpending.gov, etc.) can be utilized, the final data sources utilized for this this research include the contracts, associated work directives and cost reports. An important aspect of this analysis was crafting a relationship between the three separate data sources. One data field common across all sources was the contract number, but contract number alone enables limited insight and understanding. In other words, comparison of contract values (i.e., a macro value) offers the end user few takeaways, especially considering PTS contracts have drastically different scopes of work at each CLIN level. Additionally, an analyst might want to negate certain scopes of work like any Foreign Military Sales (FMS) efforts or other obscure efforts that were executed on the contract. Therefore, creating a relationship between the data sources at the most granular level, the SLIN (identified in Figure 2) proved to be the most effective in conducting the research detailed below.

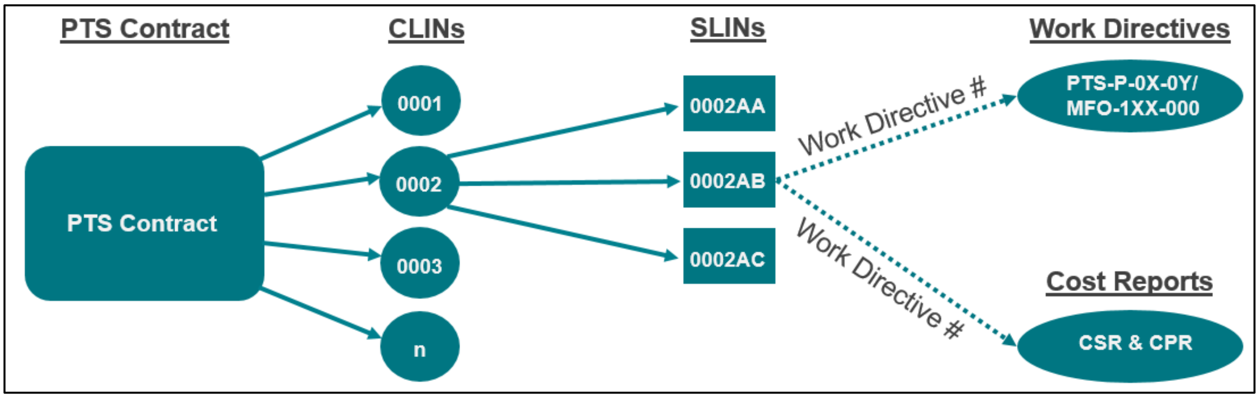

Figure 2: Data Collection Work Flow

PTS contracts for four separate Army major weapon systems, identified herein as Programs 1-4, were selected for analysis. These particular programs were selected to ensure a holistic dataset representative of the Army PTS contracts landscape. While compiling and analyzing four discrete programs' worth of PTS contracts was key to understanding the complexities of the data, the process of identifying how to best make use of the different data sources proved to be iterative over the course of the research.

Contract Data

With the scope of the data determined, the initial effort entailed retrieval of contractual information for Programs 1-4. The nature of the contracting lifecycle involves an original agreement, usually referred to as the 'Base' contract, and then subsequent modifications that alter the original agreement. Modifications have a wide array of purposes. Contract modifications can either remove or add work scope, adjust prices and/or price breakouts, change period of performances, alter funding, and perform a number of other administrative actions. The term 'contract' in the contracting world refers to this entire lifecycle with these modifications included. Therefore, any contract data collection must encompass both the Base contract and all subsequent modifications. However, this effort is not trivial as some contracts utilized in our research study contained over 200 modifications. Fortunately, there exists a conformed contract copy for all PTS contracts which provides a summary of the contract lifecycle that identifies all the contract modifications. Conformed contracts served as the primary source from which contract data was acquired.

The CLIN and subsequent SLIN information proved to be the most important aspect of the contract. It is within these sections that the most granular level of detail can be ascertained. Each CLIN and SLIN serve as a defined agreement within the contract, almost like a mini contract themselves. Price, and therefore funding, can be tied to scopes of work at either level. If SLINs exist, they fall under a specific CLIN acting as a subcategory for the parent CLIN. An example of the information relayed at the SLIN level within the native conformed contract is depicted in Figure 3:

Name of Offeror or Contractor: Contractor Name

ITEM NO	SUPPLIES/SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
CLIN #	CLIN NAME				
Sub-CLIN #	Sub-CLIN NAME	QTY #	LO	Estimated Cost Fixed Fee Not to Exceed (Funding)	$$$ $$$ $$$
	SERVICE REQUESTED: Description of service requested CLIN CONTRACT TYPE Ex. FFP, CPFF, etc. PRON: XXXXXX PRON AMD: XX ACRN: XX AMS CD: XXXXXX PSC: XXXXXX				
	WORK DIRECTIVE: XXXXX LEVEL OF EFFORT: Amount of hours			Estimated Cost: Fixed Fee:	$$$ $$$
	Estimated Labor Cost: $$$ Labor Fee: $$$ Total: $$$ Estimated Materials/ODC's: $$$ Materials/ODCs Fee: $$$ TOTAL $$$$				

Figure 3: Example of a contract template for Sub-CLIN documentation

As illustrated above, there are many data fields that are tied to the SLIN level. These fields include, but are not limited to:

- Service Requested - a brief initial overview of the service scope
- System Variant Name – vehicle variant receiving the service

- Contract type – contract vehicle (i.e. Firm Fixed Price, Cost Plus Fixed Fee, etc.)
- Procurement Request Order Number (PRON) – order number identification
- Period of Performance Start and End Date – start and end dates for when the service was delivered
- Product Service Code (PSC) - standardized category for work effort
- Not to Exceed (Funding) – amount of funding for the service
- Fixed fee – contractor profit
- Associated Work Directive Number - Work Directive identification number
- Accounting Classification Reference Number (ACRN) - two letter acronym associated with Line of Accounting (LOA) information

As noted previously, the funding information concerning appropriation and fiscal year is extracted by association with the LOA. This extracted field is critical to understanding the total resources that fund PTS efforts, as well as for conducting analysis for each of the programs studied.

Upon obtaining all the conformed contract copies and finalizing the fields necessary for analysis, the next effort revolved around extracting the data. Even with the conformed contract copy, there were still hundreds of records to obtain. In an effort to reduce manual effort, a programming language script was written to automatically extract the data. The developed code worked by ingesting the conformed contract copy and generating a flat file containing the data fields for manual validation. This methodology proved to be efficient, accurate, and repeatable across the multiple programs.

Through the contract collection phase, we gained many insights into the nature of the contracts data. One particularly interesting finding was that some PTS contracts covered multiple programs. This meant that our initial plan to tag the entirety of a contract to a single program was not valid. Therefore, instead of applying the program tag at the contract level, it had to be applied at the SLIN level. Another finding is that the scope of work associated with each SLIN was vague and lacked detail. This observation confirmed the need for collecting the work directive data.

Work Directive Data

The full picture of the services performed in the PTS contracts began to come into focus upon review of the work directives. The work directive provided the clearest understanding of the type of work being performed. In contrast to the service descriptions found in the contract CLINs and SLINs, work directives do not impose a limit on the length of its content description. This means a work directive provides details on the complete set of tasks undertaken and deliverables expected. Cost estimates and period of performance information were also included, which enabled cross validation to the information found in the contract SLINs.

One of the greatest challenges with compiling the work directive data was the limited number of historical work directive documents prior to the mid-to-late 2000s for each of the four Army programs. This coincided with a shift in the Army’s data storage practices, moving away from physical documents to digitized versions with greater accessibility. The work directive data available for the four programs studied only extended as far back as Fiscal Years 2005-07. Additionally, work directive data beyond Fiscal Year 2018 was not received for Programs 3 and 4. Therefore, for the purpose of reviewing a complete depiction of work directives across each fiscal year, the timeframe used for subsequent data collection and analysis of Programs 1 and 2 was Fiscal Years 2007-20 and Fiscal Years 2007-18 for Programs 3 and 4. Another challenge associated with the work directive data was lack of uniformity between the documents themselves. Each contractor executing work on their respective PTS contract compiled their work directive documents differently. These discrepancies resulted in a manual effort to extract information from the work directive documents.

Cost Data

While the CLINs, SLINs and work directives all contain valuable data and information related to the various aspects of the PTS contract and work executed, none of them contain the actual costs incurred. As such, the cost data for PTS contracts was retrieved from the Cost Summary Report (CSR) and Contract Performance Report (CPR) that were linked to the PTS contract for the four programs. These reports include both actual costs incurred and estimated costs at completion. A handful of the reports included additional detail in the form of costs by expenditure category (labor, material, and other direct costs). As was the case with the work directive documents, the cost reports lacked uniformity across the four programs as each contractor had a unique reporting format. These report inconsistencies led to difficulty in retrieving the expenditure categories across all four programs and limited our ability to perform uniform analysis, which shifted our focus to cumulative cost totals. Table 3 presents an example of the CPR structure for the PTS contracts studied:

			o--------------Cumulative To Date--------------o				Completion	
			BUDGET	BUDGET	ACTUAL	VARIANCE	BUDGET	ESTIMATE
WBS	Description	LEVEL	BCWS	BCWP	ACWP	COST	BAC	EAC
A01-111-000	**PTS MANAGEMENT**	**4 Hours**	**-**	**-**	**$$$$$$**	**-**	**-**	**$$$$$$**
A01-111-000	**PTS MANAGEMENT**	**4 Labor $**	**-**	**-**	**$$$$$$**	**-**	**-**	**$$$$$$**
A01-111-000	**PTS MANAGEMENT**	**4 Material $**	**-**	**-**	**$$$$$$**	**-**	**-**	**$$$$$$**
A01-111-000	**PTS MANAGEMENT**	**4 ODC $**	**-**	**-**	**$$$$$$**	**-**	**-**	**$$$$$$**
A01-111-000	**PTS MANAGEMENT**	**4 Total $**	**-**	**-**	**$$$$$$**	**-**	**-**	**$$$$$$**
A01-111-111	PTS PROGRAM ADMINISTRATION	7 Hours	-	-	$$$	-	-	$$$
A01-111-111	PTS PROGRAM ADMINISTRATION	7 Labor $	-	-	$$$	-	-	$$$
A01-111-111	PTS PROGRAM ADMINISTRATION	7 Material $	-	-	$$$	-	-	$$$
A01-111-111	PTS PROGRAM ADMINISTRATION	7 ODC $	-	-	$$$	-	-	$$$
A01-111-111	PTS PROGRAM ADMINISTRATION	7 Total $	-	-	$$$	-	-	$$$
A01-111-112	PMR SUPPORT	7 Hours	-	-	$$$	-	-	$$$
A01-111-112	PMR SUPPORT	7 Labor $	-	-	$$$	-	-	$$$
A01-111-112	PMR SUPPORT	7 Material $	-	-	$$$	-	-	$$$
A01-111-112	PMR SUPPORT	7 ODC $	-	-	$$$	-	-	$$$
A01-111-112	PMR SUPPORT	7 Total $	-	-	$$$	-	-	$$$
A01-111-113	ENG TEST	7 Hours	-	-	$$$	-	-	$$$
A01-111-113	ENG TEST	7 Labor $	-	-	$$$	-	-	$$$
A01-111-113	ENG TEST	7 Total $	-	-	$$$	-	-	$$$

Table 3: Example of Contract Performance Report

In conducting this research, the areas of focus were the cumulative cost actuals and Estimate at Completion (EAC) data sets depicted above in Table 3. These data sets provided insight into the to-date cost of the work directive efforts and highlighted the projected cost at completion. EAC data was also captured in the contracts at the SLIN level, making the results found in the report a useful resource for cross validation. In the event that a variance was discovered between the two sources, preference was given to the CSRs and CPRs. This was done for the purpose of consistency in the cost data. Estimated costs are linked directly to projections of true final cost, and as actual cost data is collected and updated, the estimates at complete can shift in response. In order to capture the inherent linkage between the two, all actual cost data was collected with its corresponding EAC.

Upon review of the CPR and CSR data for each PTS contract, we identified instances for one of the programs where service and cost were presented in finer detail than the standard work directive level, cumulating to form the total cost of the corresponding work directive. This additional level was termed ‘Sub-WD’ data to represent a subset of information that would add additional context to parent work directive scope and cost data. Table 3 provides an example of a CPR that includes cost data at a work directive (shown in bold font) and Sub-WD level of detail. The Sub-WD lines of data for this example are meant to reflect the entire tasks of the work directive service. The first and second Sub-WDs seem to support this methodology, as both present themselves as a function of program management support. However, the third Sub-WD, ‘ENG TEST’, does not appear to follow the type of tasking associated with a program management service. The most natural place to group this third Sub-WD would be in a testing category. This opens the door to questions such as, "*Is this a management effort for a testing task or does this Work Directive have more than one type of service taking place under its scope?*" The answer is impossible to pinpoint without greater clarity on the entirety of the scope. Reaching a resolution for this challenge would require a revisiting of the work directives.

Combining the Data

Compilation of the three different data sources highlighted many of the intricacies of the data universe. First and foremost, though typical of cost analysis databases, our PTS database reflects missing data. Fortunately, having three different sources of data mitigated this problem and each data source served as a cross validation for the others. Specifically, we mitigated the impact of missing data by analyzing all three data sources together.

The second challenge was inconsistency in how to relate the separate data sources together. For example, matching SLIN numbers with the associated work directives presented a challenge. In some instances, there was a simple one-to-one relationship between the two; in others there was multiple work directives for one SLIN. This made narrowing down the work effort into discrete contractual efforts very difficult. In order to mitigate this challenge, the effort of work was determined at the SLIN and work directive relationship level. This mapping allowed for multiple tags even if only one SLIN was present.

The final challenge was the difference in data reporting from the cost reports. For example, some reports had all their data tied to a specific work directive; others had all their data at the SLIN level; still others had their data reported at both. The solution to this challenge relied on performing look-ups to the specified contract data in order to accurately align the cost data with the contract data values.

Analysis

With the variety of data types collected, there were many available paths for analysis. The decision on which data to incorporate into the analysis was based on the overall goal of the research - to inform future PTS contract estimates for both current and future Army ground vehicle systems. This goal would require producing estimates that support program acquisition milestone events and underpin program budget submissions. To achieve this level of quality in an estimate, an understanding of the color of money being allocated to the correct type of cost elements has to be established. For this reason, the initial focus of the analysis was the appropriation and cost element type.

The next step was to choose if the estimated or actual cost data would be used for the cost elements in the analysis. A decision for either option depends on the results that are desired. For the purpose of this paper, the desired result was to gain insight into how the PTS contracts for the four programs were expected to look at completion, which required us to focus on the total monetary resources allocated to the PTS contracts for each of the four programs. In conjunction, significant portions of work directives were still in progress. Without reaching an end of performance, the cost actuals for a corresponding work directive could present an inaccurate depiction of the cost elements commanding the highest portion of cost by the time of completion. As a result, the decision made was to focus analysis on funding data, which accounts for both the EAC and fixed fee of the work directive effort.

The decision to focus on funding data posed a challenge, specifically at the Sub-WD level in CSRs and CPRs. Only EAC and cost actuals were reported at the Sub-WD level, leaving fixed fee and, as a result, funding to be collected from the contract SLINS. This inhibited the ability to leverage Sub-WD EAC data for funding analysis. To navigate the dilemma, an assumption was made that fixed fees would exhibit the same proportionality as EAC values at the Sub-WD level. Both the fixed fees and EAC could then be combined at the Sub-WD level to form the funding data values used in analysis.

Mapping

After establishing an approach for the analysis, the process of mapping each work directive could begin. The initial expectation was to use the Army CES to map the funding data associated with each work directive. The Army CES presents a multi-level structure to map data for costs occurring in different stages of a vehicle program life cycle. After categorizing the work directive and Sub-WD data, it became apparent that the current Army CES did not always provide an element that described the PTS work taking place.

Bearing this discrepancy in PTS work and CES mapping in mind, we created an alternative categorization structure termed ‘Service Categories’ to accurately portray the service and tasks. The intention of creating the Service Categories was to supplement the CES, not to necessarily replace it. In several instances, the Service Categories provided the best description of the PTS work being performed when compared to Army CES mapping. This alternative categorization scheme led to a better analysis mechanism across the four programs.

The Service Categories identified were tailored to the work performed in the PTS contracts, thereby making mapping to them fairly intuitive and applicable to all of the work directive services reviewed. Table 4 lists each service category created to encompass all the costing efforts:

Service Category
Program Management
Engineering Services
Logistics Services
Test / Test Support
Software Maintenance
SSTS
Development
Field Modifications / MWO
Reset / Retrofit / Overhaul
Maintenance of Leave Behind Equipment (LBE)
Fielding / Deprocessing / NET
TDP Update
Environmental
Software

Table 4: Service Categories

The list of examples below demonstrates the ability of the service categories to conform to the description of work found in the work directives (WD) for the four programs considered in our research:

- WD Scope of Work: OMA funded work for Leave Behind Maintenance (LBM) or Maintenance of Leave Behind Equipment (LBE):
- Army CES Assignment: 5.03.04 Depot Maintenance
- Service Category Assignment: Maintenance of Leave Behind Equipment (LBE)
- WD Scope of Work: OMA funded work for Logistics and Engineering efforts for RESET with Program Management:
- Army CES Assignment: 5.04.03 Sustaining/Systems Engineering
- Service Category: Reset/Retrofit/Overhaul

A set of case-based rules applicable to all four programs were established to ensure consistency in mapping to the Service Categories as well as the CES. The rules were created based on multiple reviews of the objective of individual work directives or scopes of work. In some cases, the work directive title itself was informative enough for mapping to the service category. However, in several instances, the work directive title was unclear and further investigation of the work directive's descriptive paragraphs was needed to discern a mapping categorization. Utilizing an artificial intelligence (AI) methodology to tag the data was initially considered but later dismissed because of the expertise in contextual knowledge needed to apply a mapping. Listed below are samples of frequently utilized rules throughout the mapping process for each of the four programs.

1. For a situation where the task done is different than what the task is for, map the service category to what the task is for and CES assignment to what the task is.
    a. Example WD Language: 'FSR Program Management'
        i. Service Category Assignment: FSR
        ii. CES Assignment: 2.03.02 SE/PM (Contractor) if OPA/WTCV funded; 5.0.04 Program Management if OMA funded
2. Work Directives with purposes spanning multiple task types should be mapped to the main task. The main task will usually be included in the Work Directive Name.
    a. Example WD Language: 'ECPs with Program Management'
        i. Service Category Assignment: ECP
        ii. CES Assignment: 2.02.02 Recurring Engineering
3. Work split between two distinct types of work (e.g., SEPM and TDP Update) should be mapped to the broadest category to capture the PTS work.
    a. Example WD Language : 'Procurement funded SEPM and TDP update'
        i. Service Category Assignment: Engineering Services
        ii. CES Assignment: 2.03.02 SE/PM (Contractor)
4. Procurement funded and having anything to do with existing software (e.g., software. modifications), map to:
    a. Service Category Assignment: Software Maintenance
    b. CES Assignment: 2.11 Software Maintenance
5. RDT&E funded work and predominately program management, map to:
    a. Service Category Assignment: Program Management
    b. CES Assignment: 1.05.02 SE/PM (Contractor)

By establishing a set of rules, human error in mapping decisions related to changes in thought process over the course of review was minimized. Overall, the rules standardized the funding categorization, which in turn lead to more accurate results for the analysis and subsequent observations.

In the cases where a work directive could not be collected, all mapping information for work directives and Sub-WDs had to be based on only their respective title descriptions found in CSRs and CPRs or CLINs from the contract. Neither option would present a reliable understanding of the complete service performed, making mapping without a work directive document largely impossible.

Observations

With a complete collection of mapped data, our analysis into each program considered:

1. PTS funding summary by year
2. Appropriation distribution
3. Funding by CES
4. Service category funding across fiscal years

Within the analysis, observations into the activities that might explain the data trends are highlighted and potential programmatic events are identified for the various service categories.

PTS Summary

Table 5 consists of a ‘Heat Map’ that presents top level PTS funding, expressed as a percentage of total program funding, by program by year for the timeframes addressed in our research (Fiscal Years 2007-20 for Programs 1 and 2; Fiscal Years 2007-18 for Programs 3 and 4).

Year of Associated Funding	Program 1	Program 2	Program 3	Program 4		Legend
2007	1%	21%	2%	2%		
2008	11%	22%	22%	4%		
2009	15%	18%	31%	4%		
2010	2%	7%	8%	9%		
2011	1%	2%	8%	1%		
2012	4%	7%	4%	17%		
2013	1%	6%	11%	8%		
2014	2%	3%	3%	12%		
2015	9%	2%	2%	13%		
2016	9%	5%	5%	16%		
2017	13%	4%	3%	11%		
2018	16%	2%	1%	3%		
2019	6%	2%	0%	0%		>10% Funding
2020	8%	0%	0%	0%		>5% Funding
Total %:	**100%**	**100%**	**100%**	**100%**		>0% Funding
Total (TY$M):	**493.2**	**1516.8**	**250.5**	**377.4**		0% Funding

Table 5: PTS funding for Programs 1-4 by FY (Program 3 and 4 data not received for FY 2019-20).

The following observations are derived from analysis of the data and trends in Table 5:

- Funding from the PTS contracts for all four programs are not allocated in a uniform manner across fiscal years.
- Cases of spikes in the levels of funding by fiscal year occur in each program over the research study timeframes.
- The percentage for each programs' highest surge in PTS funding over a four year period is:
  - Program 1: 47%
  - Program 2: 68%
  - Program 3: 69%
  - Program 4: 52%
- PTS funding for Program 1 has two peaks, one peak during Fiscal Years 2008-09 and another during Fiscal Years 2017-18. Together, these peaks consumed over half (55%) of the program's total PTS funding from Fiscal Years 2007-20.
- Program 2 allocated 61% of funding from the PTS contracts in Fiscal Years 2007-09.
- Program 3 received a large surge in funding in Fiscal Years 2008-09 (51%) and has an overall trend of decreased funding from Fiscal Years 2007-18. This trend is also exhibited in Program 2.

- Program 4 has a lower peak in percentage of funding, but has a longer ramp up and ramp down in funding surge.

Appropriation

As discussed at the beginning of this paper, and presented in Figure 1, funding can be categorized into the following appropriations: Research, Development Test & Evaluation (RDT&E), Procurement, Military Construction and Family Housing, Military Personnel and Operations and Maintenance (O&M). PTS contracts are used for many types of services aligned with Procurement funding, but can also package substantial additional costs within a major weapon system program lifecycle that are funded with alternative appropriations. Figure 4 illustrates the distribution of PTS funding by appropriation for Programs 1-4:

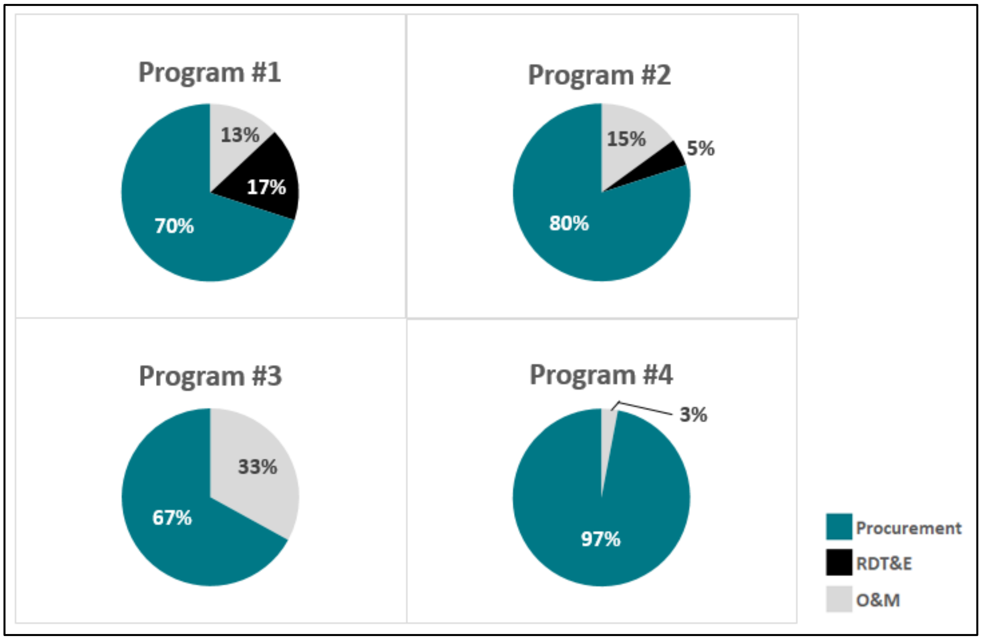

Figure 4: Appropriation distribution of PTS Funding for Programs 1-4

The following observations are derived from analysis of the data and trends in Figure 4:

- Procurement funding (OPA/WTCV) is the predominant PTS funding source for all four programs, representing an average of 78.5% of PTS funding across the four programs.
- Future Army vehicle programs can expect Procurement appropriation to consume as much as 97% of total PTS funding and, in turn, can also prepare for Procurement to be responsible for as little as 67% of total PTS funding.
- Different funding tolerance situations:

- Program 3 – 33% OMA funding; Program 4 – 0% OMA
- The larger percentage of OMA funding in Program 3 potentially indicates that Program 3 had more excess funding to use on expenses.
- RDTE appropriated funding can vary greatly depending on the initial development effort, the stage of the program's life cycle under review, and any intensive engineering efforts taking place throughout the program's life cycle that exceed the scope of engineering change proposals.

Associated Cost Element

Table 6 presents a second 'Heat Map' of the funding distribution by Army CES, highlighting the elements that received the largest portions of funding for PTS services.

Associated Cost Element	Program 1	Program 2	Program 3	Program 4
1.01 Development Engineering	$1,536,570	$14,014,890	$0	$3,285,582
1.03 Development Tooling	$0	$0	$0	$4,750
1.05.02 SE/PM (Contractor)	$511,111	$60,841,646	$0	$7,253,536
1.06 Systems Test and Evaluation	$0	$811,781	$0	$696,319
1.07 Training	$0	$26,835	$0	
1.08 Data	$0	$36,538	$0	$2,468,937
2.02.02 Recurring Engineering	$12,814,807	$4,392,461	$0	$0
2.03.02 SE/PM (Contractor)	$153,676,257	$928,840,190	$86,970,756	$159,223,693
2.04 Systems Test and Evaluation	$15,386,597	$10,327,648	$0	$10,638,492
2.05 Training	$9,695,558	$0	$0	$1,107,976
2.06 Data	$11,014,105	$45,505,188	$41,058,000	$97,123,478
2.09.03 Initial Support Equipment	$2,163,708	$9,961,565	$0	$0
2.09.05 New Equipment Training	$0	$0	$6,058,740	$0
2.09.06 Contractor Logistics Support	$30,279,292	$66,362,338	$0	$0
2.11 Software Maintenance	$61,216,828	$101,764,917	$0	$18,613,121
2.12 Technical Refresh	$2,169,032	$4,421,823	$0	$0
2.14 Other Procurement	$28,673,729	$0	$1,226,499	$0
5.01.02 Unit-Level Maintenance	$5,783,451	$79,493,965	$7,735,474	$0
5.02.02 Support Services	$4,727	$8,227,155	$0	$0
5.03.03 Intermediate Maintenance	$1,881,026	$30,331,978	$0	$0
5.03.04 Depot Maintenance	$33,509,060	$57,495,667	$74,068,443	$0
5.04.01 System Specific Training	$8,677	$3,556,886	$0	$0
5.04.03 Sustaining/Systems Engineering	$9,254,230	$16,760,332	$8,495,877	$0
5.04.04 Program Management	$12,041,742	$20,684,918	$0	$0
5.04.06 Data and Technical Publications	$0	$15,888,196	$0	$0
5.05.01 Hardware Modifications	$0	$0	$17,629,390	$8,411,585
5.05.02 Software Maintenance	$0	$3,165,785	$0	$0
Unmapped Funding	$101,539,238	$33,850,085	$7,223,902	$68,560,926

Legend
>10% Funding
>5% Funding
>0% Funding
0% Funding

Table 6: PTS funding across Army CES for Programs 1-4

The following observations are derived from analysis of the data and trends in Table 6:

- CES 2.03.02 Systems Engineering and Program Management is the primary consumer of funding. This coincides with the results found from the analysis into Appropriation funding distribution.
- Two of the four programs have higher than 10% of their PTS funding tied to services that were unable to be mapped. This is a result of work directives that could not be obtained and, in turn, accurately mapped.

Service Category

As depicted in Table 4, fourteen unique types of service categories were created. Analysis and observations focus on the three service categories receiving the largest percentage of funding from the PTS contracts for their respective program. Figures 5-8 display the results for Programs 1-4.

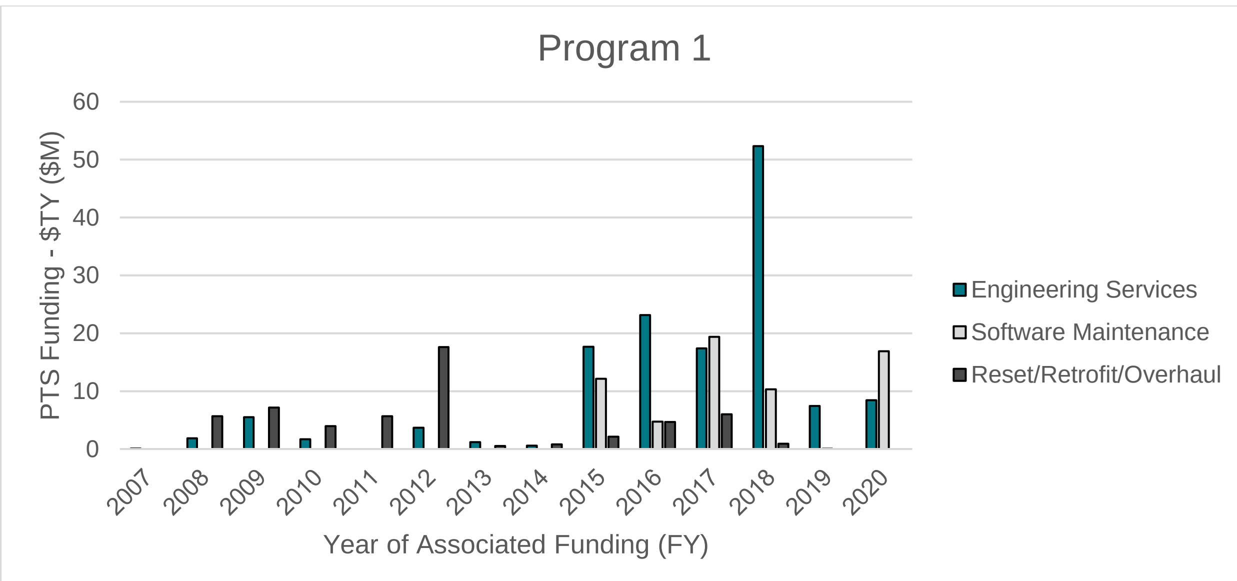

Figure 5: Three highest funded Service Categories for Program 1 from FY 2007-20

The following observations are gleaned from analyzing the data and trends in Figure 5:

- The three highest funded Service Categories are:
  - Engineering Services: 36%
  - Software Maintenance: 16%
  - Reset/Retrofit/Overhaul: 14%
- A significant surge in Engineering Service funding occurs from Fiscal Years 2015-18

- An Engineering Services spike in Fiscal Year 2018 accounts for 37% of the service and 11% of the entire PTS funding of the program for Fiscal Years 2007-20.
- The increase in funding levels for Engineering Services could suggest a major programmatic event, possibly in the form of an engineering change proposal.

- A Reset/Retrofit/Overhaul funding spike takes place in Fiscal Year 2012, indicating a potential overhaul point in the program life cycle.
- The funding levels for Software Maintenance occurring across Fiscal Years 2015-2020 display an overall uniform distribution

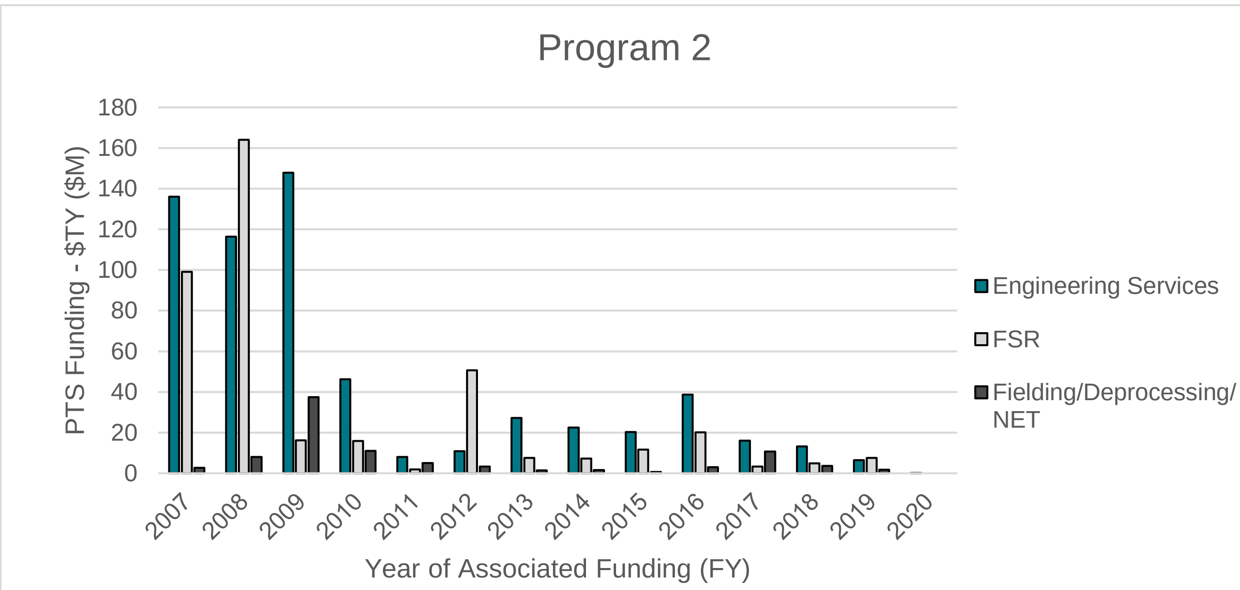

Figure 6: Three highest funded Service Categories for Program 2 from FY 2007-20

The following observations are gleaned from analysis of the data and trends in Figure 6:

- The three highest funded Service Categories are:
  - Engineering Services: 40%
  - FSR: 27%
  - Fielding/Deprocessing/NET: 6%
- Each of the three highest funded Service Categories see their highest amount of funding occur between Fiscal Years 2007-09.
- Fiscal Years 2007-08 are representative of 18% of the total PTS funding for Program 2.
- Fiscal Years 2007-09 are representative of 26% of the total PTS funding for Program 2.
- Fielding/Deprocessing/NET funding is a fraction the size (~ 20%) of FSR funding.

- The overall trend of the top three highest funding service categories across the period of study match, supporting the idea that these services have an effect on each other.
- Vehicles in theater / combat operation scenarios could drive surge in Fielding and FSR funding that takes place from Fiscal Years 2007-09.

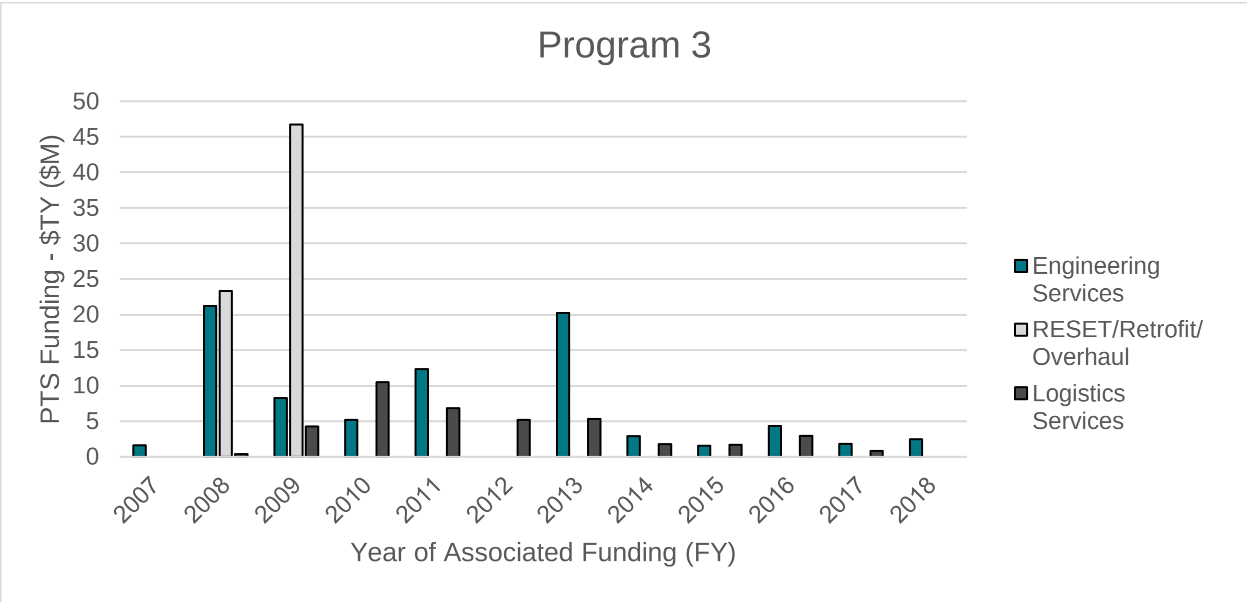

Figure 7: Three highest funded Service Categories for Program 3 from FY 2007-18

The following observations are gleaned from analysis of the data and trends in Figure 7:

- The three highest funded Service Categories are:
  - Engineering Services: 34%
  - Reset/Retrofit/Overhaul: 29%
  - Logistics Services: 16%
- Reset/Retrofit/Overhaul service effort received ~$70M in funding across Fiscal Years 2008-09, accounting for 100% of this service's PTS funding during the research study timeframe.
- There are two funding spikes for Engineering Services in Fiscal Year 2008 and Fiscal Year 2013 that account for 51% of total Engineering Service funding for Program 3.

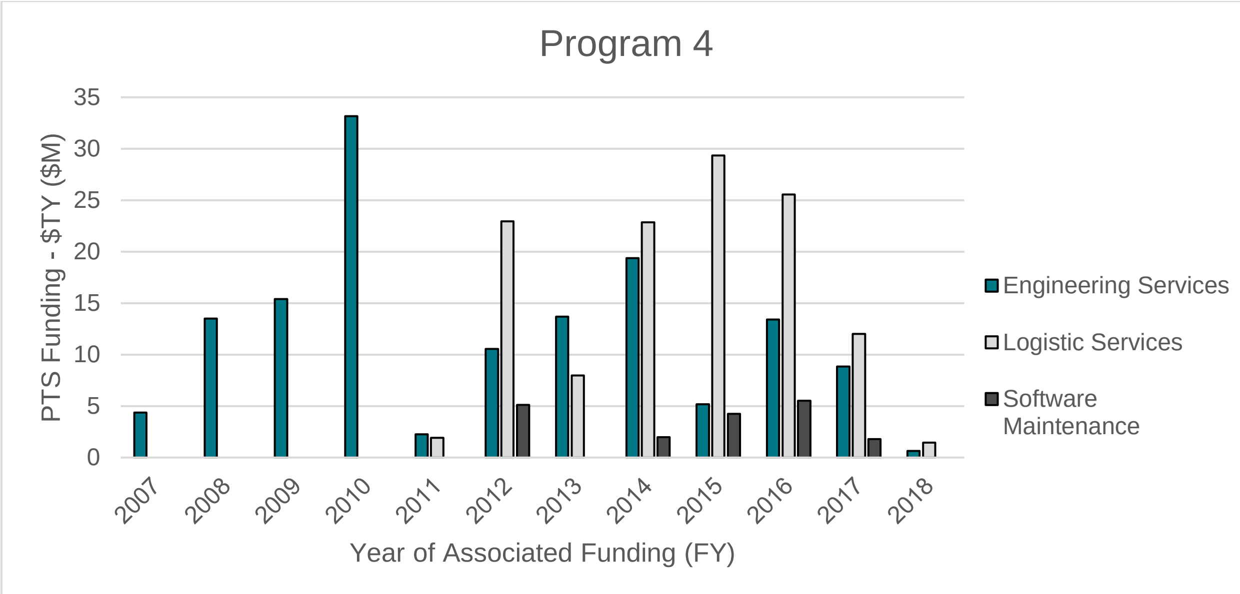

Figure 8: Three highest funded Service Categories for Program 4 from FY 2007-18

The following observations are gleaned from analysis of the data and trends in Figure 8:

- The three highest funded Service Categories are:
  - Engineering Services: 43%
  - Logistic Services: 38%
  - Software Maintenance: 6%
- A spike in Engineering Services funding in Fiscal Year 2010 consumes 24% of the service category's funding and 9% of total PTS funding for Program 4.
- Software Maintenance service displays relatively static funding level from Fiscal Years 2012-17. This suggests a consistent effort in maintaining software in the vehicle for this program.
- Logistic Services also has a uniform trend from Fiscal Years 2012-17. This consistency at +$20M funding values suggests a sustained, large-scale fielding effort occurring for Program 4 during Fiscal Years 2012-17.
- The funding growth occurring for Engineering Services from Fiscal Years 2007-10 and Fiscal Years 2011-14 may correspond to a ramp up in engineering updates to the vehicle program.

Proposed Solutions

At the conclusion of the data collection phase, many of the nuances and inconsistencies of the data were realized. These inconsistencies are present because the various programs and contractors have different reporting standards and procedures. Therefore, creating meaningful analysis started with formulating a process that would be robust enough to encompass the different data challenges. However, crafting an all-encompassing solution presents its own drawbacks as the analysis can become convoluted. This section serves to address the challenges that made the analysis difficult at times and offers solutions to streamline analysis in the future.

Work Directive, CLIN and Cost Data Relationships

The challenge paramount to the entire analysis was how to strategically combine the three discrete data sources. Comparing the different data fields depended upon the commonality of the fields across the sources and ease of tagging these fields. The common fields found were the contract number, CLIN, SLIN, and work directive. As previously mentioned, the relationship between these fields differed from each source. For example, the relationship between SLIN and work directive were sometimes one-to-one and other times one-to-many. Another challenge was the cost report reporting level; some reports were on the SLIN level and others were on the work directive level. Ultimately, these challenges were mitigated but could have been avoided entirely.

Through performing the analysis and reviewing all the data sources, the most authoritative and accurate data source remained the contract. This data source proved to be the most important as it is the vehicle in which goods and services are agreed upon for a certain price. Therefore, having the relationships structured around the contract is imperative for streamlined analysis. It is imperative that the cost reports present data at the most granular contract level (CLIN/SLIN) to enable quick comparison against contract price and price breakouts. Additionally, since work directives inform contractual actions, each accepted work directive should translate to a separate SLIN on the contract. This effort would ensure that the scope of each can be easily ascertained from the work directive and quickly compared to the SLIN that performs the prescribed work. This one-to-one mapping would ensure color of money and fiscal year funds can be directly translated to the scope of work.

Mapping Subjectivity

The other challenge critical to the entire analysis is mapping the work efforts to the CES and the Service Categories. In general, data tagging, is accompanied by the uncertainty of whether the data should be bucketed in one group or another. Our PTS analysis is no different. While some of the data tags are cut and dry, others remain subjective and can fit into multiple groupings. An often-proposed solution is to simply create another bucket, but at what point does that logic end? The answer is it never does, one would eventually have such a specific mapping tag that it would be useless.

While the perfect mapping strategy will never exist, there is a step that can mitigate the issue. Each work directive is written by the contractor in great detail before being awarded on a contract. Therefore, the contractor will always be the expert in relation to the specific scope of work for a work directive and subsequent contract actions, should the awarding agency place the effort on contract. Assuming the work directive is placed on contract, the PCO could require the contractor to identify the CES element and/or Service Category most closely associated with the scope of work. Although the PCO (or someone else with Government contracting authority) would need to cross-check the validity of the CES or Service Category assignment, this tagging system could lend itself to enhancing the development of permanent mapping rules for PTS scopes of work over time.

Recommended Path Forward

The analysis presented in this paper demonstrates how systematically mapping the CES and the created service category to the combined data sources result in uncovering the funding spent on work efforts. The approach we employed can be applied to any PTS contract to uncover and breakdown the entire price. However, while this approach is complete, it also serves as a launching point for future analysis.

Cost Actuals Completeness

As previously mentioned, meaningful analysis depends on having a complete dataset. An obvious point for exploration in future studies is to have final costs incurred and integrate them into the study. This completed dataset lends itself to multiple facets for examinations. A useful analysis would be the comparison of the contract prices to the cost actuals themselves. This comparison could inform the government if certain service categories are prone to incur cost overruns or be more/less profitable than others. Another approach would be to compare the specific contract price breakout with the cost actuals. Since many of the contract types are CPFF, an analyst could examine the values at a more granular level than just the SLIN price. Lastly, this completed cost dataset could be utilized to better understand cost and schedule changes over time.

Time Series Data

In order to fully analyze cost and schedule changes over time, an analyst would need to evaluate the complete contract lifecycle. A key shortcut we took in our research involved utilizing the conformed contract copy. However, a more complete analysis would involve tracking the contractual data as it changes modification-by-modification. This complete picture of the data would provide valuable insight into when specific prices, schedules, and work efforts were altered. This analysis would enable an analytical view similar to Figure 9:

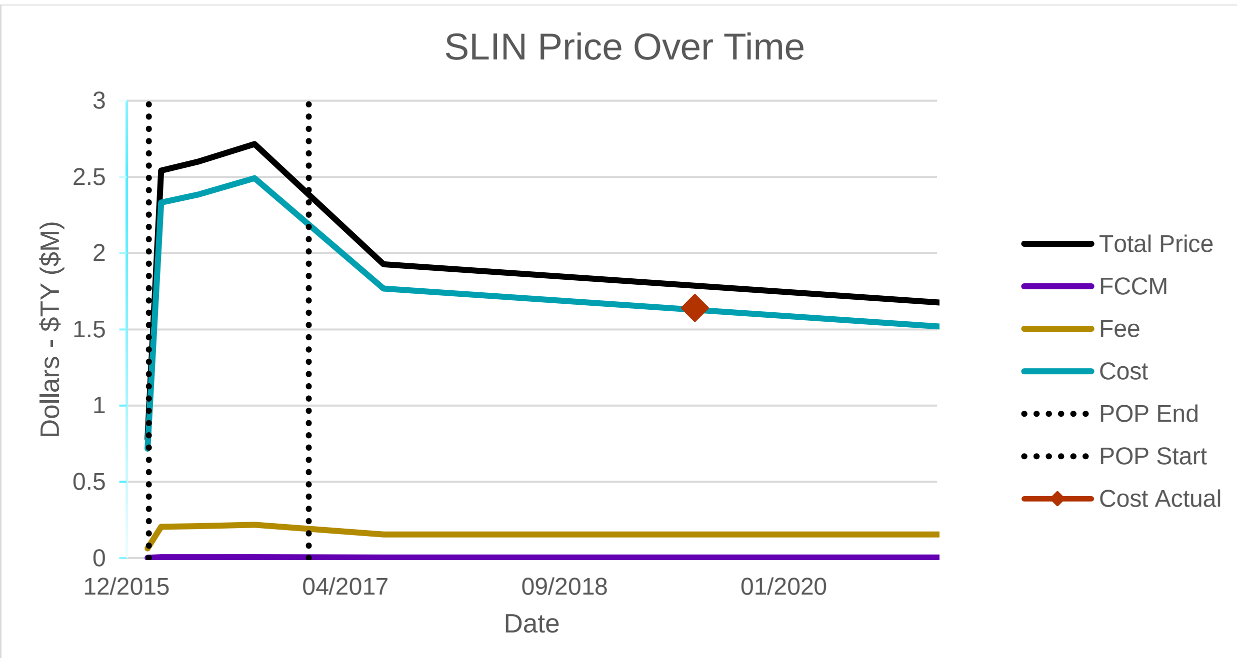

Figure 9: SLIN Price over Time

Conclusions

As demonstrated throughout this paper, PTS contracts are an extremely valuable contracting mechanism utilized by the Army and other services to acquire a broad array of technical support, maintenance and other services to help keep weapon systems sustained throughout their lifecycle. However, as our research indicates, there is room to achieve significant progress in terms of how the contracts are structured relative to the Army CES in order to enhance the usefulness of PTS contracts in budgeting for future technical support requirements. As currently structured, it is next to impossible to accurately assess how total funding and actual costs incurred for a particular PTS contract are distributed across CES elements. As this research has established, properly linking and tagging data across PTS contract CLINs, SLINs, work directives and cost reports relative to the Army CES can tremendously enhance the understanding of what the major cost drivers are within PTS contracts. With the Army CES serving as one of the cornerstones for how Army budgetary requirements get established, this linking and tagging is absolutely critical.

As alluded to in the introduction of this paper, the Army is in the midst of a modernization effort that is likely to shape the capabilities and effectiveness of its ground combat vehicle fleet for decades to come. By replicating some of the analysis and implementing some of the recommendations presented in this paper, the Army will not only get a better understanding of where it has been with PTS contract funding relative to legacy ground vehicle systems, it will position itself to properly budget for the Next Generation Combat Vehicle (NGCV) fleet and the capabilities its systems will have, as well as the sustainment funding levels these systems and their new technologies will require.

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Biographies

Alex Bonich, an Associate with Technomics, Inc., has over a year of experience in the defense industry. For the past year, he has supported the Army in the development of Life Cycle Cost Estimates for various vehicle programs. Prior to joining Technomics, Alex began his professional career at General Dynamics Land Systems as a Mechanical Engineering contractor. He graduated with academic honors and a B.S.E. in Mechanical Engineering from the University of Michigan.

Rhys Bergeron, a Lead Analyst with Technomics Inc., has over 3 years of experience supporting government entities. Rhys specializes in using data science skills to empower government analysts to exploit and make use of their data. Many of his projects involve building ETL (Extraction, Transform, and Loading) processes, creating automation scripts to scrape information, engineering databases, and building analysis tools. Rhys is an ICEAA member and holds a B.S. in Chemical Engineering from Virginia Tech.

Pat McCarthy, a Program Manager with Technomics, has over 19 years of experience in Federal and private industry performing cost analysis and Industrial Engineering studies. He has previously worked as a Cost/Price Analyst and Team Lead with Booz Allen Hamilton and the Army Contracting Command and as a Senior Industrial Engineer and Team Leader with General Dynamics Land Systems. Pat is CCEA and PMP certified and holds B.S. and M.S. degrees in Industrial Engineering from Purdue University.