Effects of Performance Based Logistics Contracts on Naval Aviation Costs and Requirements

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An F/A-18E Super Hornet assigned to the Nighthawks of Strike Fighter Squadron (VFA) 136 lands aboard the aircraft carrier USS Enterprise (CVN 65) during a joint task force exercise to prepare for an upcoming deployment.

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Executive summary

Over the past decade, performance-based logistics (PBL) contracts have become increasingly prevalent across the Naval Aviation Enterprise. These PBLs have been widely incorporated at both the component and system level. Generally, under a PBL contract, a service provider is given a fixed payment for providing the Navy with a sufficient level of parts or repair services to satisfy certain performance levels specified in the contract. The intent of the PBL is to give the contractor the incentive to provide the parts or services most efficiently. However, there is concern that the expected savings from PBLs have not been realized.

In this study, we examined the effect PBL contracts have had on Naval aviation costs and requirements. As part of this larger issue, we also addressed the following questions:

- Are particular features of PBL contracts associated more strongly with cost reduction?
- What have been the trends in PBL renewals and their implications for costs?
- What does the value and "must-pay" nature of PBL contracts imply for how budgetary fluctuations impact non-PBL budgets?

Findings

We gathered and analyzed data on the Navy's aviation PBL contracts. We also used aviation cost and maintenance data. Our findings are summarized here.

Statistical evidence suggests that PBLs have yielded savings of 12 percent relative to traditional support, though this estimate falls just shy of the conventional threshold for statistical significance; the

largest savings from PBLs are for items with lower total expenditures.

We compared the costs to support more than 5,000 parts that came under a PBL arrangement with other parts on the same aircraft that remained under traditional support. Although we estimate that the average expenditure growth for parts was 12 percent lower under PBL than in the non-PBL comparison group over the same time period, this estimate has a wide margin of error. In particular, we cannot rule out, with sufficient confidence, the possibility that PBLs have had a neutral overall effect on cost.[1] This estimate represents the effect of PBLs on cost after adjusting for any readiness changes under PBL. That is, it reflects the estimated difference between PBL and traditional support in the cost to achieve a given level of readiness.

This estimate reflects historical performance of PBLs and does not imply that converting future items to PBL support would save an equivalent amount. Items that went under PBL make up a selected sample. Every potential PBL contract must undergo a business case analysis (BCA) test that requires no increase in cost relative to traditional support.

An interesting finding is that we observed the largest savings rates for parts that account for a smaller share of overall total expenditure. This finding is consistent with the notion that more expensive items may receive greater management attention to cost reduction whether under traditional support or under PBL. In particular, we estimate statistically insignificant savings of 12 percent for items ranked in the top 20 percent according to total expenditures, but statistically significant savings of almost 40 percent for items ranking in the lowest 20 percent.

We also estimate savings separately for PBLs at the component level, the sub-system level, and the system level. PBLs at the component level are associated with the largest savings (17.7 percent), whereas we find statistically insignificant savings of 7 percent among PBLs at the sub-system level. We estimate system-level PBLs savings of 10

1. Our 95-percent confidence interval for the overall effect of PBLs on cost ranges from -24.4 percent to +2.7 percent.

percent. The estimate for system-level PBL savings makes sense if we think of system-level PBLs as covering a combination of sub-systems and components. We find, as expected, that the estimated savings for system-level PBLs lie between the savings from PBLs at the component and at the sub-system levels.

PBLs have contributed to improved readiness.

We found that turnaround time and not-mission-capable-for-supply (NMCS) time have both declined where PBLs have been introduced. Our estimates suggest these metrics are between 15 and 42 percent lower under PBL than under traditional support.

Our cost model suggests measurable savings can be realized by reducing readiness levels.

According to our model estimates, a 10-percent increase in not-mission-capable time spent awaiting parts is associated with a 1- to 2-percent drop in total cost.

Contract characteristics associated with savings include longer contract length and fewer platforms supported. Awarding the contract competitively is also associated with higher savings.

We examined various features of PBL contracts and found that only a few were strongly associated with savings. In particular, a competitively awarded PBL saves between 19 and 45 percent more than a sole-source award. Longer PBL contracts and those that support fewer platforms also increase savings.

Renewals have yielded savings similar to initial contracts.

There is concern that PBL contract renewals will cost more than the initial contract because the contractor has an incumbent advantage. However, we found that PBL renewal contracts tend to produce cost outcomes similar to initial contracts, suggesting that the concern about renewals may not be occurring in practice.

The must-pay effects of PBLs may not be as large as feared.

PBLs are often thought of as must-pay bills because the Navy is contractually obligated to make payments. The budgetary inflexibility introduced by PBLs may be somewhat lower than commonly believed. PBLs that are paid by the flight hour (often referred to as "power-by-the-hour" PBLs) represent almost exclusively variable costs. Also, other PBLs specify a range (or band) around targeted flying hours or number of repairs for which the fixed payment is applicable. If budgets are cut and flying hours fall below these bands, the Navy has the right to renegotiate to a lower amount paid under the PBL. Similarly, if the Navy exceeds the upper limit on targeted flight hours, the contractor could ask for a larger payment. However, for small fluctuations around targeted flight hours, the PBL cost is essentially fixed.

We estimate that up to 43 percent of the aviation depot-level repairables (AVDLR) budget becomes a fixed cost if we account for PBLs. This figure implies that absorbing a 1-percent cut in the total AVDLR budget would require a 1.7-percent cut in the budget for non-PBL AVDLRs.

The decision of whether to provide support through a PBL or through traditional contracting continues to be made on a case-by-case basis. Program officials told us about PBL contract opportunities that were not pursued because the BCA did not show a cost equivalent to or better than the non-PBL alternative. The data examined in this study support the proposition that the Navy's aviation PBL selection process, overall, has produced contracts that improve readiness for the same or lower cost.[2]

Recommendations

We offer a number of recommendations based on our findings.

- Overall, the case-by-case application of business case analysis used to select appropriate PBLs should be continued. On balance, the evidence suggests that the PBLs we observe (all of which were subject to business case analysis) have improved readiness and have not increased cost relative to traditional support.

2. Although we estimate lower cost under PBLs, it bears repeating that our estimate falls just short of the conventional threshold for statistical significance.

- At this time, estimates of the effects of PBLs on cost are not statistically reliable enough to recommend any substantial revision to the current budgeting models used to project future aviation logistics requirements. As we accumulate additional data over time, such an effort may become worthwhile.

- We found evidence that suggests competition may improve savings. As a result, we recommend exploring competitive PBL awards wherever practical.

- Finally, the data reveal a measurable tradeoff between cost and readiness. In light of the Navy's concerns with preserving more short-term operational flexibility, we recommend exploring the feasibility of structuring future PBL contracts in a way that allows different payments for different service levels or flight hours.

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Introduction

Background

Over the past decade, the Navy has shifted a substantial portion of its aircraft repair budget to performance-based logistics (PBL) contracts. Table 1 lists the set of currently active PBL contracts.

Table 1. Active PBLs by size (FY 2009 obligations)

Contracting office	PBL name	FY 2009 obligations, $millions, then-year
NAVAIR	T-45 F405 engines PBTH	84.2
NAVAIR	V-22 engines AE1107C PBTH	39.5
NAVAIR	KC-130 engines AE2100D3 PBTH	22.7
NAVAIR (Lakehurst)	CASS support equipment	29.4
	Subtotal, NAVAIR	**175.8**
NAVICP	H-60 Tip to Tail	222.3
NAVICP	F/A-18 engines F414 Depot Components	148.2
NAVICP	F/A-18 engines F404/ F404 Option	146.4
NAVICP	F/A-18 FIRST	140.8
NAVICP	F/A-18 engines F414 C & A / Fleet Support	85.7
NAVICP	AV-8B HISS	50.9
NAVICP	F/A-18/F-14 HUD/DDI	32.1
NAVICP	H-60 engines T-700	30.0
NAVICP	S-3/E-2/C-2/F-18-A-D/P-3 APU's	29.9
NAVICP	Common ALR-67(v)3	23.7
NAVICP	H-53 Phase I	23.2
NAVICP	P-3 APS-137B	13.5
NAVICP	H-60 FLIR	12.7
NAVICP	Common Tires	12.1

Table 1. Active PBLs by size (FY 2009 obligations)

Contracting office	PBL name	FY 2009 obligations, $millions, then-year
NAVICP	Common Avionics ARC-210	9.5
NAVICP	H-46/H-53 APUs	7.5
NAVICP	Common: Advanced Mission Computers	5.9
NAVICP	Common ALQ-126B	5.8
NAVICP	F-18/F-14/AV-8 SMS	5.5
NAVICP	EA-6B Hydraulics	4.8
NAVICP	Common Avionics: CAINS II	4.7
NAVICP	H-46 Comp Phase I	4.5
NAVICP	F/A-18 SMUG	3.3
	Subtotal, NAVICP	**1,022.9**
	Total	**1,198.7**

Taken as a group, the PBL contracts accounted for almost $1.2 billion in FY 2009. The eight largest contracts accounted for 75 percent of all PBL costs. The contracts we studied include both Navy and Marine Corps aircraft.

Aviation PBL contracts are managed by Naval Inventory Control Point (NAVICP) and Naval Air Systems Command (NAVAIR). These are revolving fund activities that make payments to the contractors and, in turn, recoup the costs of the contracts through charges to the fleet (the end users). Costs for PBL contracts ultimately are paid for out of the Aviation Depot Level Repairables (AVDLR) or Maintenance accounts of the Navy's flying-hour program (FHP) or the aviation depot maintenance budget. Table 2 provides some perspective on the percentage of these respective budgets that were covered under PBL contracts during FY 2009.

Table 2. Distribution of PBL funding across aviation budget categories

Funding category	FY09 actual obligations ($millions, then-year)	FY09 PBL obligations ($millions, then-year)	Percent under PBL
FHP, AVDLR	2,136	1,023	32%
FHP, Maintenance (consumable parts)	1,039		
Depot maintenance (O&MN, 1A5A)[a]	1,313	176	13%

a. Operation and Maintenance, Navy, Air Operations (1A) budget activity group, Aircraft Depot Maintenance (5A) subactivity group

PBL characteristics

Under a traditional support arrangement, the Navy orders a set number of expected replacement aircraft parts or repairs from suppliers and pays a negotiated per-part price. Under this framework, suppliers have little incentive to make reliability improvements to parts, as it would mean fewer future sales. Furthermore, the Navy cannot guarantee that parts will be available and delivered within a certain amount of time, potentially leading to aircraft downtime and decreased readiness.

Under a PBL, the Navy enters a fixed-price, longer-term contract with the supplier to provide any needed repairs or replacements for a defined set of parts. The PBL specifies one or more performance metrics tied to readiness (such as maximum wait time). The performance metric and fixed price together provide the supplier a stronger profit incentive to improve readiness at reduced cost. Any reduction in cost the contractor can achieve (without sacrificing performance) is captured as additional profit. A thorough background discussion of PBLs and their application in the Navy and Marine Corps can be found in [1] and [2].

PBL contracts have historically taken many forms. The PBLs we focus on in this study are commonly referred to as “Full” or “Partnership” PBLs. These forms entail the greatest degree of contractor responsibility for the supply chain. Specifically, these types of PBLs are defined in the logistics community as follows:

- Full PBL (PBL-F)—A contractual arrangement where the contractor manages (and may also own) the inventory, determines stockage levels, typically repairs Not-Ready for Installation (NRFI) material, and is required to meet specific performance metrics. Requisitions still flow through the inventory control point (ICP), and ICP pays the contractor for performance, but customers are billed in a traditional manner. Reliability improvements, technology insertion, and reduced obsolescence may be some of the inherent benefits of a PBL-F. The contractor usually is given Class II Engineering Change Proposal (ECP) authority and, in some cases, may also have configuration control. In addition, Logistics Engineering Change Proposal (LECP) arrangements will be considered a subset of this category if they contain supply support clauses that fall under the definition noted above. All Integrated Logistics Support (ILS) elements can be covered in a full or partnership PBL if funding resources are properly allocated.

- PBL-Partnership (PBL-P)—A PBL-F that incorporates a partnership between a commercial entity and an organic depot. This arrangement is between a contractor and the Navy such that the Navy performs a portion of support required by and for the contractor. For example, the contractor may subcontract the Navy to perform maintenance support at an organic depot. This can be highly beneficial when addressing core maintenance issues, in that the Navy is able to retain core capability while acting as a "sub" to the contractor.

Some PBLs specify a price per item demanded or per flight hour.[3] Others have a fixed price within a band around targeted flying hours or items demanded. The target allows the contractor to reasonably predict the number of failures, consequent repairs, and resulting cost. On the basis of this expected cost, the contractor can set a reasonable fixed price to charge for the PBL. If flight hours end up exceeding the target by too much, the contractor would have to do many more repairs than planned for, and would be at risk for financial loss. For that reason, an upper flight-hour band is written into the contract. It protects the contractor by providing an

3. These contracts differ from traditional support in that they require the contractor to meet specified performance metrics tied to readiness.

opportunity to renegotiate a higher payment if flight hours (and repairs) end up exceeding the planned level by more than a specified percentage. On the other hand, if flight hours end up substantially below the planned level, the fixed price paid by the Navy would be well above the contractor's actual repair cost. For this reason, a lower band is specified in the contract. It protects the Navy from overpaying in the event of an unexpected drop in flight hours.

For example, a contract may have a targeted flying-hour level of 5,000 hours with an upper band of 10 percent and a lower band of 15 percent. This means the payment is fixed if flight hours end up anywhere within the band (between 4,250 and 5,500). If flight hours are outside this band, the parties will be able to renegotiate a different price.

Virtually all of the PBL contracts we examined use some form of turnaround-time metric. Parts are grouped according to priority and must meet contractually specified average and maximum time between requisition and delivery. These times vary depending on whether the requisition originated from inside or outside the continental United States (CONUS or OCONUS). Additional metrics used in the V-22 engine power-by-the-hour contract are:

- Accommodation rate (gross effectiveness): This metric is calculated as the ratio between total carried demand and total demands. It is a measure of whether the correct items are carried in the inventory being maintained. Total carried demands include requisitions that are immediately issued from stock, in addition to requisitions that are carried but currently out of stock.
- Net effectiveness: This metric is calculated as the ratio of total issues to total carried demands. It is a measure of whether the contractor is stocking sufficient quantities of items carried in the inventory.
- Material availability: This metric is calculated as the ratio of total demands issued within a specified timeframe to total demands. It is a measure of how quickly (on average) the contractor is able to fulfill demands that arise.

The T-45 engine PBL uses availability and minimum engine release life metrics. The latter metric is used to ensure that, in meeting the availability requirements, the contractor is using only engines with sufficiently long remaining expected life.

Before awarding any PBL, the Navy performs a business-case analysis (BCA) to determine whether it would be cost-effective compared with the traditional support alternative. Cost-effectiveness can be thought of as either higher readiness at the same or lower cost, or the same or higher readiness at lower cost. Although BCAs provide a forward-looking estimate of the potential cost-effectiveness of individual PBLs, a backward-looking, post-PBL analysis of actual historical data can be useful as well.

In this study, we used data on PBLs managed by NAVAIR and NAVICP to examine the effects that Naval aviation PBLs have had on recent support costs and readiness. We considered whether these effects depend on characteristics of the contracts, whether contract renewals perform differently than their predecessors, and what all of these effects imply for future support requirements. Because of their must-pay nature, PBLs may also constrain flexibility within aviation budgets in responding to overall budget changes. Building on prior work, we calibrated a model that illustrates the degree of flexibility given up.

Effects of PBLs on costs and readiness

Our analysis of the effect of PBL contracts on costs and readiness focused on AVDLR costs because the bulk of PBLs cover AVDLRs.

Estimation methodology

Ideally we would like to have observed what would have been the cost of repairing and replacing individual parts—also referred to as National Item Identification Numbers (NIINs)—had they not come under PBLs. Given the absence of this counterfactual comparison group, we instead made comparisons with the group of NIINs on the same aircraft type-model-series (TMS) that were not covered by a PBL.[4] This approach had the advantage of controlling for the effects of any unmeasured influences on reliability or cost (such as changes in the operating environment or above-inflation growth in raw material costs) that might affect PBL and non-PBL component costs in a similar fashion.

One caveat to this approach is that, even though both groups of parts come from the same aircraft, they are still two different sets of parts. Also, we assume that the effects of PBLs on the cost to support non-PBL items are small relative to other cost drivers. One example of such an effect might be that reliability improvements due to PBL may require fewer removals of PBL-covered items, resulting in lower

4. Another potential approach is to estimate the difference in cost of the NIIN while under a PBL and the earlier cost of the same NIIN before coming under a PBL. This is the general approach taken in [3] for a subset of PBL contracts. The authors report a 12-percent increase in cost. We were able to replicate and confirm their findings using their smaller sample of PBL contracts. The advantage of using this comparison group is that, because they are the same set of NIINs, we don't have concerns about differences in the characteristics of the products themselves skewing the results. One weakness of this approach, however, is that unobserved determinants of repair costs may change over time.

risk of accidental damage (hence lower support cost) to non-PBL items during the removal process. Another example might be training provided by PBL field representatives to squadron maintenance personnel, which may have beneficial "spillover" effects for non-PBL items.

Estimation model

Our model specifies a parametric relationship between the relative cost of PBL parts to non-PBL parts and:

- Flight hours per aircraft
- Number of aircraft
- Average downtime caused by a missing part
- Whether a PBL is in place.

Flight hours are a standard determinant of cost used by the Navy's flying-hour program to estimate aviation budget requirements. By including it in our model, we allow for the possibility that flight hours may have different effects on the cost of PBL and non-PBL parts. Total flight hours are decomposed into flight hours per aircraft (average flying intensity) and total number of aircraft. This decomposition allows for the possibility that more intensive flying and adding more aircraft may have different effects on relative cost even if the total flight hour increase is the same in each case. We include average downtime, measured by not-mission-capable-for-supply (NMCS) time associated with the part, to capture any additional cost associated with improved readiness.

Our main regression equation is given by

$$\ln(c_{ijt}) = \alpha_{ij} + \beta \ln(FH_{jt} / AC_{jt}) + \gamma \ln(AC_{jt}) + \lambda(NMCS_{ijt} / D_{ijt}) + \delta PBL_{ijt} + \varepsilon_{ijt}$$

The variables are defined as follows:

- c_{ijt} is the cost of PBL part (NIIN) i relative to the cost of all non-PBL parts on aircraft TMS j in period t. The period reflects either the pre-PBL or post-PBL period. We calculate total cost by valuing demands at NAVICP net prices.

- FH_{jt} are the total flying hours for aircraft TMS j in period t.
- AC_{jt} are the total number of aircraft TMS j in period t.
- D_{ijt} are the total demands for part i on aircraft TMS j in period t.
- $NMCS_{ijt}$ are the total not-mission-capable hours of aircraft type j in period t due to supply, awaiting NIIN i (higher uptime should cost more).
- PBL_{ijt} indicates whether NIIN i for aircraft type j is covered under a PBL in period t. (A value of 1 indicates PBL coverage.)
- α_{ij} is a fixed effect for NIIN i on TMS j. This term accounts for unobserved differences across individual items that are constant over time.
- ε_{ijt} is a random error.

Further technical details regarding the derivation of this estimation model are contained in appendix A.

Data

NAVICP provided us the set of NIINs covered by each PBL in our sample, as well as the dates at which the PBL coverage started and ended (or was renewed under a new contract). The level of observation is a NIIN-TMS pair, as the same NIIN often appears on multiple TMSs. We pulled monthly demand and cost data for this set of NIIN-TMSs from the Navy Aviation Maintenance and Material Management (AV3M) database, covering the fiscal years 1998 through 2010. To form our comparison set, we also pulled aggregate monthly demand and cost data for all NIINs, by TMS, that never went under PBL. We refer to this set as “non-PBL NIINs.”

We converted all costs to constant 2009 dollars using the Office of the Secretary of Defense (OSD) Green Book Operation and Maintenance, Navy (OMN)-less fuel deflator, obtained from the Naval Center for Cost Analysis website.

The cost data we observe over any fixed number of months (or sample window) are necessarily censored because there are parts that may have an expected time to failure that is longer than the sample window. If the post-PBL sample window is longer than the pre-PBL window, we may observe higher cost simply because a part has had more time to fail in the post-PBL window, not necessarily because the PBL is more costly. Therefore, to minimize any effects due to differential censoring effects between the pre-PBL and post-PBL, we trimmed our sample so that we observed the same number of months in the pre-PBL and post-PBL period (whichever is less) for each NIIN-TMS.[5] We next aggregated the monthly data to form, at most, two observations (one pre-PBL, one post-PBL) corresponding to each NIIN-TMS pair.

Summary statistics

Appendix B gives the summary statistics of our sample. The tables report summary statistics for groups of NIIN-TMSs. In most cases, a PBL corresponds to a single group. For some PBLs, however, new groups of NIINs were added to the PBL at different times. As a result, there are cases in which an individual PBL corresponds to a number of NIIN-TMS groups.

PBL effects on cost

Appendix C presents the full results of our regressions. Here we discuss the key findings.

5. We trimmed the months farthest from the initial PBL award date. For the pre-PBL period, this meant trimming the earliest months; for the post-PBL period, the latest months.

PBL effects on overall cost

Before turning to the estimation results of our main equation on the *relative* cost of PBL items, we first look only at what has happened to the real (inflation-adjusted) *absolute* cost of PBL items (reported in column (1) of table 14 of appendix C). We see that, on average, they have increased by more than 21 percent.[6] However, this does not measure what PBLs have saved relative to traditional support, because many other things might have changed to cause higher costs over time. The above-inflation cost growth for PBL items may be due to material or labor cost growth between the pre-PBL and post-PBL periods. Such factors would have conceivably also driven costs higher had the items remained under traditional support.[7]

To account for such cost changes that may be affecting all parts (both PBL and non-PBL) more or less equally, we examine (in columns (2) and (3) of table 14) how the cost of PBL items has changed relative to the cost change of non-PBL items on the same TMS during the same period. Note that the dependent variable used in columns (2) and (3) is relative cost, c_{ijt}, as described earlier in our explanation of the estimation model. Column (2) of table 14 reports our estimates if we assign equal weight to every NIIN-TMS pair, and column (3) gives our estimates when we weight NIIN-TMSs in accordance with total spending during the entire sample period. The weighted effect is a better indicator of the aggregate savings, whereas the unweighted estimate represents a straight average of the savings rates from each NIIN-TMS pair.

The estimated coefficient on the PBL indicator variable in column (3) suggests savings of 12 percent, although this is statistically significant only at the 90-percent level. The unweighted estimate in column (2) is significantly higher (22-percent savings), suggesting that NIIN-TMS pairs with lower weight (lower total spending) tend to have higher savings rates. We explore this further later.

6. Using the average observed pre-PBL and post-PBL time of approximately 4.7 years, we calculate this cost growth as 4.3 percent per year.

7. A number of studies, such as [4] and [5], have pointed out the above-inflation growth in AVDLR costs and have sought to explain it.

The parameter estimate on the number of aircraft variable is not significantly different from zero, which suggests that changes in the number of aircraft affect the cost of PBL and non-PBL parts similarly. However, we find that changes in flying intensity (flight hours per aircraft) have a significantly greater effect on the cost of PBL parts than on the cost of non-PBL parts. This result may be an indication that parts that are accepted by contractors under PBL are those that have more predictable relationships between flight hours and failure rates. Costly parts with less predictable failure rates may be considered too risky by contractors to include in a PBL arrangement.

As expected, we find a negative effect on cost of higher NMCS per demand. Reducing NMCS time per demand means providing a higher level of service, which should cost more. However, this effect is modest, suggesting small savings from reducing logistics performance.[8] For example, calculations using our estimates suggest that increasing NMCS time per demand for a specific NIIN-TMS by 10 percent would reduce cost for that NIIN-TMS by about 1.1 percent.[9]

Effects on cost, by type of PBL

To assess whether there was a difference in savings between component-level and system-level PBLs, we used a classification of PBLs provided by NAVICP to estimate our model separately for each type of PBL (table 3).[10] Most PBLs in our sample cover sub-systems.

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8. We measure only one aspect of quality, NMCS hours. Quality may vary in other dimensions as well.

9. We calculated this elasticity of 0.11 as the product of the estimated slope of NMCS hours per demand (reported in column (3) of table 14) and mean NMCS hours per demand of 511.

10. To improve sample size, we grouped PBLs that cover single or multiple components together. Similarly, we grouped PBLs that cover single or multiple sub-systems together.

Table 3. Classification of PBLs by type

Component-level PBLs	Sub-system-level PBLs	System-level PBLs
F/A-18 engines F414 Depot Components	T-45 F405 engines PBTH	H-60 Tip to Tail
F/A-18 engines F414 C & A / Fleet Support	V-22 engines AE1107C PBTH	F/A-18 FIRST
S-3/E-2/C-2/F-18-A-F/P-3/C-130 APU's	KC-130 engines AE2100D3 PBTH	CASS support equipment
H-53 Phase I	F/A-18 engines F404/ F404 Option	
Common Tires	AV-8B HISS	
H-46/H-53 APUs	F/A-18/F-14 HUD/DDI	
EA-6B Hydraulics	H-60 engines T-700	
H-46 Comp Phase I	Common ALR-67(v)3	
	P-3 APS-137B	
	H-60 FLIR	
	Common Avionics ARC-210	
	Common: Advanced Mission Computers	
	Common ALQ-126B	
	F-18/F-14/AV-8 SMS	
	Common Avionics: CAINS II	
	F/A-18 SMUG	

The results of our separate regressions are shown in table 15 of appendix C.

We find the strongest savings are associated with component-level PBLs (as reported in column (1) of table 15). Sub-system-level PBLs (as reported in column (2) of table 15) have estimated savings that are statistically insignificant. For system-level PBLs, we estimate savings of 10.4 percent, though this estimate is significant only at the 10-percent confidence level. The savings estimate for system-level PBLs is between the estimate for component-level PBLs and that for sub-system-level PBLs. Intuitively, this seems reasonable if we think of system-level PBLs as encompassing multiple components as well as sub-systems.

We also performed separate regressions by type and model of aircraft. The results of this analysis did not differ in any meaningful way from the overall results and are not included in this paper.

Effects on cost, by total expenditure quintile

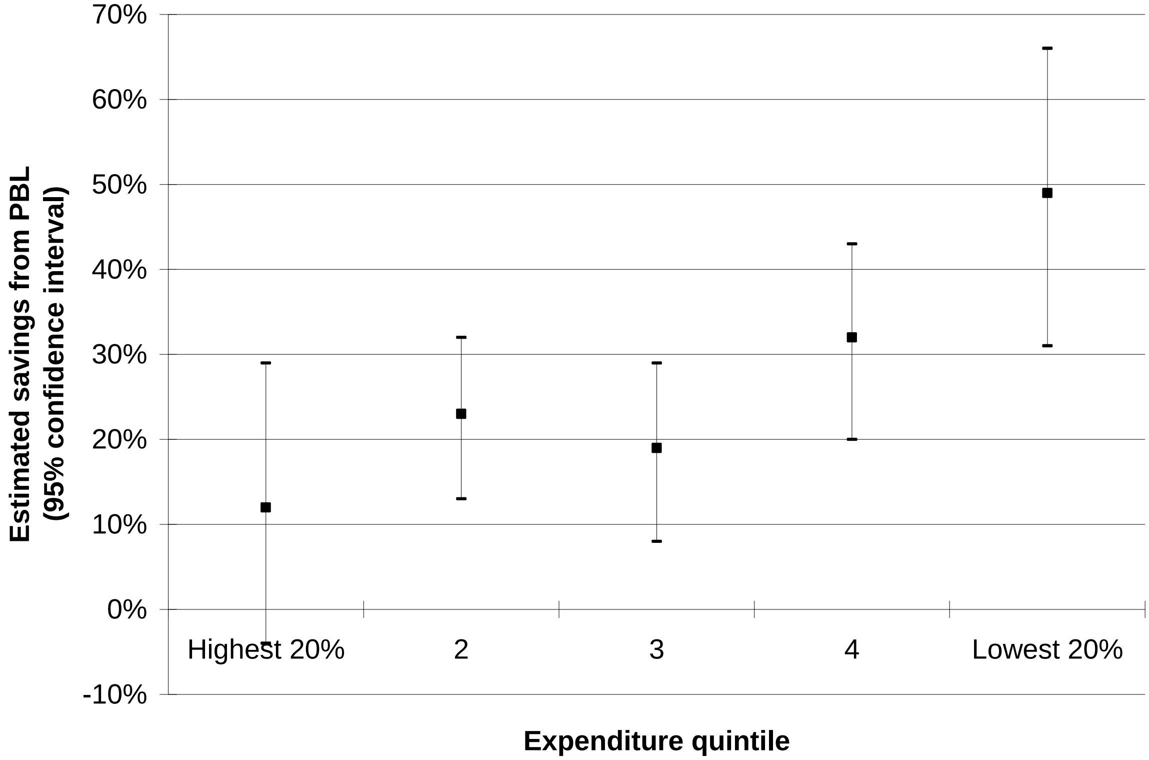
To explain the marked difference in results between the unweighted and weighted model, we grouped the NIIN-TMS observations by quintile according to their individual weights in the sample. Recall that the total weight assigned to a NIIN-TMS is proportional to the total amount that was spent on it in our sample (both pre- and post-PBL). The top quintile represents the highest-expenditure items and the bottom quintile represents the lowest-expenditure items. The total cost represented by each of the quintiles is given in table 4. The top quintile accounts for more than 93 percent of the total cost in our sample.

Table 4. Total cost quintiles of NIIN-TMS PBL items

Quintile	Number of NIIN-TMS	Share of total cost (%)
Top	925	93.4
4th	925	4.9
3rd	926	1.3
2nd	925	0.4
Bottom	926	0.02

We estimated our model for each quintile separately and found that the savings rate from PBL increases as we move down in value. This finding is consistent with a story that larger-expenditure parts may have already been receiving management attention with respect to cost control prior to coming under a PBL. The full regression results are shown in table 16 of appendix C. Figure 1, below, depicts the 95-percent confidence intervals associated with the estimated savings (denoted by the black squares) in each expenditure quintile reported in table 16. It illustrates how savings associated with PBL have been greater for smaller-spend items. For example, the line in figure 1 corresponding to the "Highest 20%" category represents the estimated savings from PBLs among the highest 20 percent of NIIN-TMS pairs, ranked according to cost. It is also worth noting that the estimates on the flight hours variable in table 16 of appendix C indicate items in the lower-expenditure quintiles have costs that are proportionally less responsive than non-PBL part costs to flight hours.

Figure 1. Estimated savings from PBL, by NIIN-TMS total expenditure quintile



PBL effects on logistics performance metrics

Next, we examine the effect of PBLs on a number of logistics performance metrics. In particular, we examine their effects on

- Total and relative demand per flight hour
- NMCS hours per demand
- Wait time per demand.

The estimation results are detailed in table 17 of appendix C. We find that PBLs are associated with declines in NMCS hours per demand and wait time per demand. We also find a decline in demand when our data are unweighted, but no change in demand when we weight the data according to total spending. These results mirror those we found for relative cost and suggest that reliability improvements have played a role in cost reduction.

Effects of PBL contract characteristics on cost

Table 18 of appendix C contains the regression results for our examination of various contract characteristics. The specific characteristics we examined were:

- Length of contract:[11] We expect longer contracts to have two opposing effects on the level of savings. First, longer contracts might yield greater savings by providing a longer horizon over which to earn returns on potential investments in improved reliability. At the same time, longer contracts may shift more cost risk to the contractor. As a result, the contractor may require compensation in the form of a higher contract payment.

- Magnitude of flight-hour bands: We expect that a higher top band, because it imposes more cost risk to the contractor, would result in lower savings. A lower bottom band means higher expected profit to the contractor;[12] hence, it should be associated with lower cost.

- Metric count: A large number of detailed performance metrics may constrain contractors, add to reporting requirements, or reflect higher contracted-for quality of service; hence, it may increase cost.

- Platform count: A greater number of platforms supported may allow for economies of scale. We use the number of TMSs supported under the PBL as the measure of platform count.

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11. We measure contract length in years, including the base contract plus all options.

12. In the event that flight hours turn out to be lower than targeted (but still above the bottom band), the contractor is paid the full amount but presumably incurs lower cost.

- Degree of competition: Competitively awarded PBLs may yield more savings.

In table 5 we present the sample summary statistics for these characteristics. The mean values represent the average across NIIN-TMS pairs that experienced some demand over our study period, and not over PBL contracts.

Table 5. Summary statistics for PBL contract characteristics

Variable	Mean (unweighted)	Standard deviation	Minimum	Maximum
Contract term (years)	6.6	4.6	1.7	15.2
Upper flight-hour band (percentage above target)	14.3	9.1	0	25
Lower flight-hour band (percentage below target)	14.3	9.1	0	25
Metric count	4.6	2.1	2	8
Platform count	5.8	4.9	1	29
Competed	0.05	0.2	0	1

We estimated unweighted and weighted regressions of the effect of these contract characteristics on relative costs. For the weighted regression, the weight applied to a particular NIIN-TMS was the total expenditure for that NIIN-TMS in our sample. The results of these regressions are reported in table 18 of appendix C. We find that PBLs that were awarded competitively yield between 19 and 45 percent greater savings. Despite the statistical significance of this finding, it is important to note that only four PBL contracts have been competitively awarded to date. The estimates also indicate that longer contracts are associated with slightly larger savings (approximately 2.8-percent greater savings per additional year), though this result is statistically significant only in the weighted regression. Each additional platform supported is associated with 3.1-percent higher cost per NIIN-TMS. This effect is also statistically significant only in the weighted regression.

The coefficient estimates for the lower and upper flight-hour bands are consistent with our expectations, though they are statistically insignificant.

Trends in AIMD billets

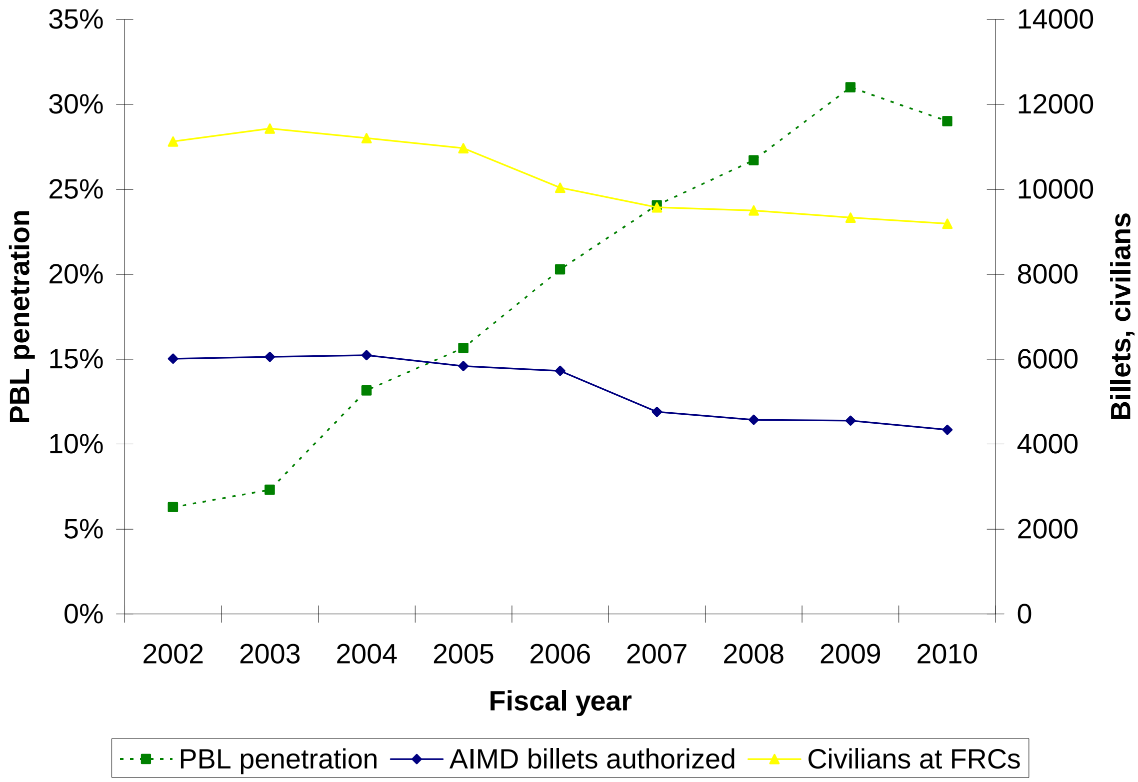
In this section, we investigate whether there is a correlation between the extent of PBL coverage and aviation maintenance and supply personnel. In particular, we examine whether PBLs have enabled military manpower reductions in Aviation Intermediate Maintenance Departments (AIMDs) as more repairs and supply chain functions are handled by PBL contractors. We were unable to associate AIMD personnel to particular TMSs. As a result, military manpower costs were not included in the regression results reported earlier. Instead, we examine broad trends. If nothing else had changed, we would expect to see flat-to-declining AIMD personnel as PBL penetration has increased.

We gathered data on AIMD authorized billets in aviation maintenance and supply over time and examined whether changes in their levels are consistent with increased PBL contracting, both in absolute numbers as well as after accounting for flight-hour changes. The results are only suggestive, because we are unable to control for other policy changes (for instance, maintenance process changes independent of PBLs) that may also be influencing the number of AIMD personnel.

As a result of the 2005 Base Realignment and Closure (BRAC) recommendations, AIMDs were merged into fleet readiness centers (FRCs). As part of this realignment, some military billets were converted to civilian positions. To get a broader perspective of AIMD personnel changes over time, we also examined total civilians at FRCs over time.

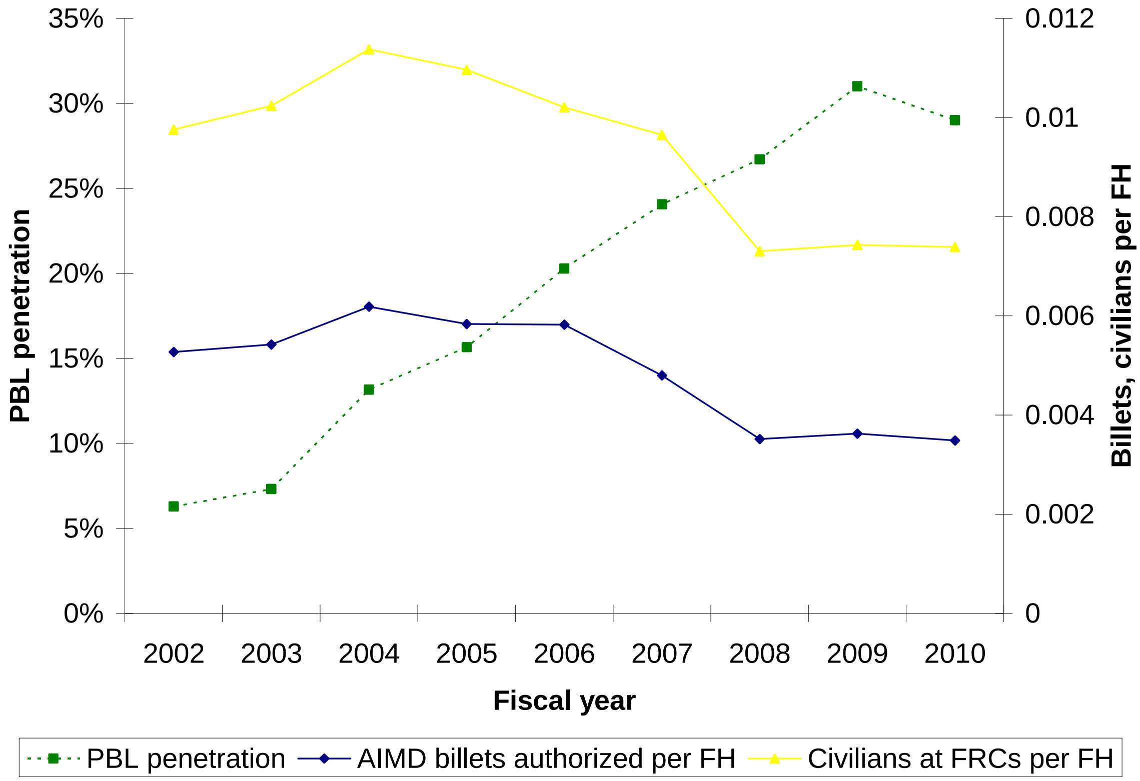
Figure 2 plots PBL penetration (measured on the left axis), total AIMD billets authorized (measured on the right axis), and FRC civilians (measured on the right axis) over time. We measure PBL penetration as total NAVICP obligations for aviation PBLs as a percentage of total FHP AVDLR and maintenance budgets.

Figure 2. AIMD billets authorized and FRC civilians vs. PBL penetration, 2002–2010



We observe that, as the percentage of repairs and replacements covered by PBL has increased, the number of authorized billets at AIMDs has come down. The number of civilians at FRCs has also declined during this period.

Figure 3. AIMD billets authorized and FRC civilians per flight hour vs. PBL penetration, 2002–2010



In Figure 3, we present a similar graph, this time accounting for flight-hour changes. We see that AIMD personnel per flight hour and FRC civilians per flight hour have each declined by approximately one-third between 2002 and 2010; in the same period, PBL penetration increased from around 5 percent to roughly 30 percent. Overall, these trends indicate that the direction of the change in AIMD personnel is consistent with expectations.

It was beyond the scope of this study to estimate specific military personnel savings associated with particular PBL initiatives. This remains an open question that future research may address.

PBL renewals

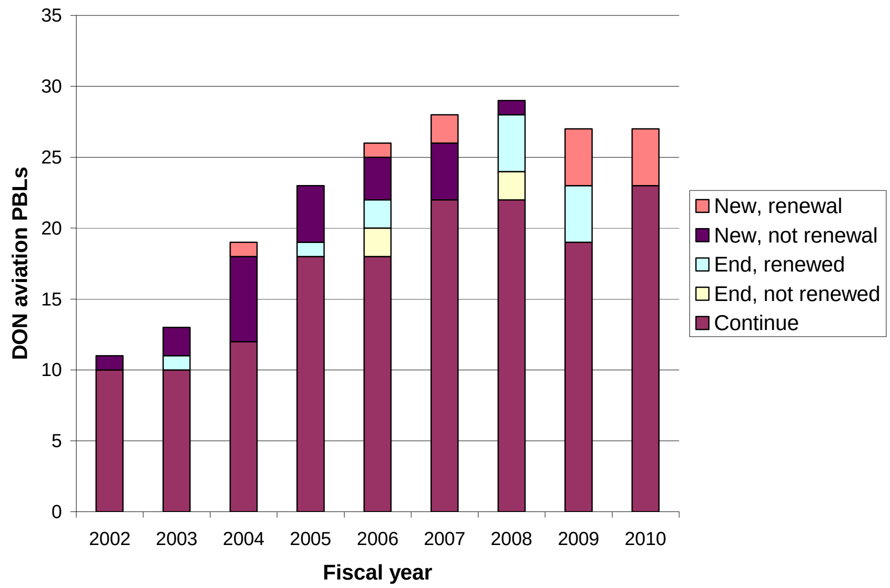
When a PBL comes up for renewal, there is a concern that the incumbent contractor will be able to bargain for a higher price because the Navy has given up its ability to provide organic support. In this section, we discuss recent trends in PBL renewals as well as the effects of PBL renewals on cost.

Trends in PBL renewals

Figures 4 and 5 illustrate the outcomes of Navy PBLs since 2002. (Figure 4 measures the count of PBL contracts; figure 5 the value of PBL contracts.) In each year, the overall height of the bar indicates the full count or value of active PBLs in that year. Among the active contracts in each year, we broke out those that were new (further subdivided between renewals and those that are completely new) and those that were ending (further subdivided between those that were renewed and those that were not).[13]

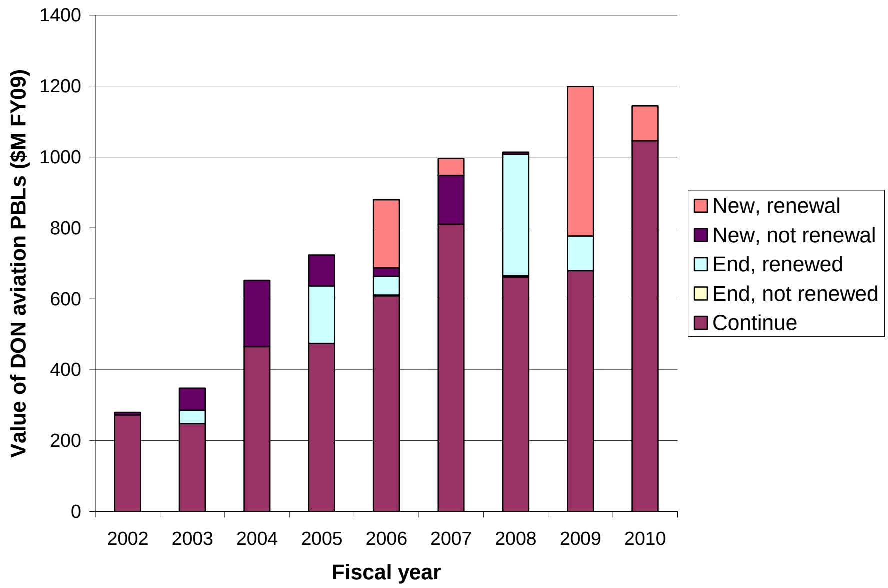
13. We were unable to obtain precise historical expenditures for the V-22 and KC-130J power-by-the-hour PBL contracts. As a result, they are excluded from the historical analysis. These have each been renewed in the past 5 years.

Figure 4. Outcomes of Navy aviation PBLs, contract count 2002–2010



The figures illustrate the growth of PBL contracts over time. All new PBL contracts since FY 2008 have been renewals, which suggests a recent slowdown in the expansion of PBL coverage. However, new parts are often added to a renewal PBL, so that some expansion of PBL coverage still occurs through PBL scope increases at the point of renewal. This increase in scope partially accounts for the increase in value under PBLs between 2008 and 2009 even as the number of active PBL contracts went down.

Figure 5. Outcomes of Navy aviation PBLs, contract value 2002–2010



Few PBLs (with almost negligible value) have not been renewed. These trends suggest that, in almost all cases, when a contract comes up for renewal, the Navy still finds the PBL to be cost-effective compared to the alternative of returning to traditional support.[14]

Effects of renewal PBLs on cost

In light of the concerns with PBL renewals expressed earlier, as well as the growing importance of "renewal" PBLs, an important question is whether a PBL renewal costs more than the initial contract.[15]

14. NAVICP officials told us that for some PBL renewal BCAs they are unable to compare the proposed PBL to a traditional support alternative, because information on traditional support is out of date. In these cases, the existing PBL contract is used as the benchmark.

15. The contractor may be able to bargain for a larger profit margin at the time of renewal (compared with the original contract), even as the Navy enjoys lower overall cost under the renewal. We do not observe the contractor's profit margin and cannot address this question.

To address this question, we adapt the estimation model we used earlier to assess what happens to support costs when a PBL contract is renewed.

The results of this estimation are shown in table 19 of appendix C. In the weighted regression results (presented in column (2)), we observe that PBL contracts and renewals overall have a statistically insignificant impact on cost. From the unweighted regression results (presented in column (1)), we calculate that the average savings rate for a NIIN-TMS covered under a PBL is 16.3 percent, with an additional 12.4 percent if the PBL contract is a renewal. Thus, in each case, the savings estimate for a renewal PBL is not less than an initial PBL, and may in fact be larger. These results indicate that the Navy is not being "held up" at the time of renewal.

Budget execution flexibility under a PBL

Because many PBL contracts commit the Navy to pay a specified amount, independent of actual demand, they impose some loss of budget flexibility on the Navy. When an unanticipated cut occurs to the aviation budget in an execution year, typically it means the Navy must reduce its flying hours for the remainder of the year. In the presence of fixed costs that have to be paid, a given percentage cut to the overall budget may translate into a much larger required cut in flight hours. The corollary to this principle (though a circumstance not encountered as often) is that the existence of fixed costs implies that flight hours can be increased by a greater percentage than a given percentage budget increase. In this section, we describe and calibrate a relationship between budgets and affordable flight hours that highlights the potential constraints imposed by PBLs.

We build on the model described in [6]. Because the bulk of PBLs cover AVDLRs, we limit our focus to these items.

Fixed and variable nature of PBL costs

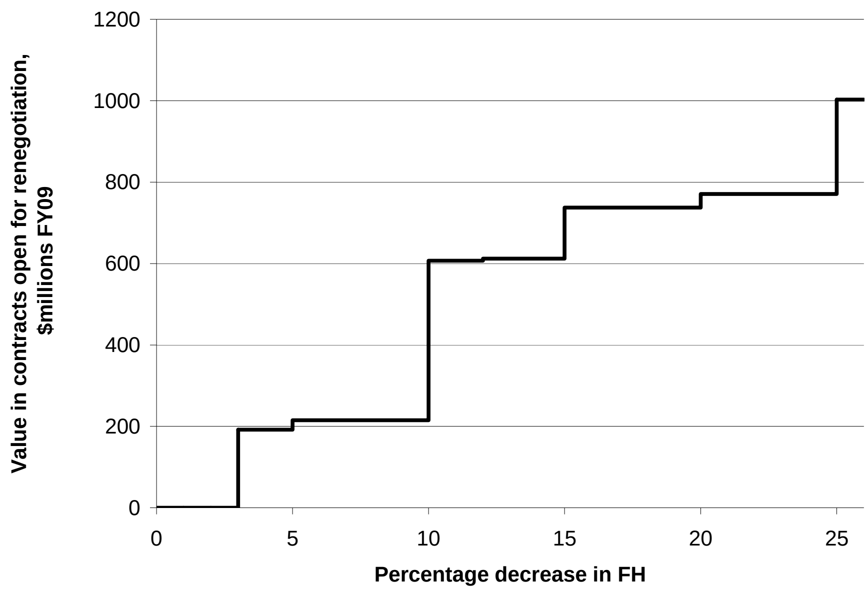
PBL contracts may not represent as large a loss in budget flexibility as commonly perceived, for at least three reasons.

First, some PBLs are purely variable costs. These represented about 16 percent of the value of all aviation PBLs in FY 2009, and they include the "power-by-the-hour" contracts. To the extent that these contracts allow the Navy to reduce its own maintenance infrastructure, they may actually improve budget flexibility (relative to traditional support) by converting some previously fixed costs into variable costs.

Second, for PBL contracts that specify a fixed payment, the costs are fixed only within the flying-hour (or demand) bands specified in the contract. The size of these bands varies by individual contract.

Most contracts specify that the parties are to renegotiate if the bands are crossed. This means the Navy should be able to reduce its total payment to the PBL contractor if flying hours or demands are sufficiently below the anticipated level. Figure 6 illustrates how decreases in flight hours would increase the total value in contracts with crossed bands. The figure includes all contracts in our sample that have flight-hour bands. Also, we assume the same decrease in flight hours applies to all TMSs.

Figure 6. Value in contracts open for renegotiation as flying hours decrease, $millions FY 2009



Third, to the extent that PBL contracts take over some of the functions of the supply system typically considered as overhead, there is (or ought to be) an offsetting reduction in the fixed cost the Navy incurs by operating its own supply system. The cost of NAVSUP personnel and facilities that are required to administer the wholesale supply functions of AVDLR stocking are generally considered fixed with respect to the number of AVDLR demands, for a fixed set of AVDLRs. However, it is conceivable that the costs of those functions may be variable with regard to the number of different AVDLR items managed.

We assume that there is a fixed cost of renegotiation once the bands are crossed (we choose 2 percent of the value of the contract for purely illustrative purposes), but, after paying this fixed price, the Navy's cost is reduced by the change in variable costs attributable to the drop in flight hours.

Model of flight hours and AVDLR budget with PBL

To account for the effect of PBLs on fixed cost, we adapt the model developed in [6].[16] In particular, we begin with the baseline figures provided in [6], shown in table 6, and we make three modifications. First, we assign PBLs that are priced per flight hour or per unit of demand entirely to variable costs. We make offsetting adjustments to the baseline cost categories. Second, we assign PBLs that have fixed prices (within specified bands) to a new fixed-cost category, again making the necessary offsetting adjustments to the baseline cost items. Finally, we consider the respective effects of 5- and 10-percent declines in flight hours. In the event of such declines, the Navy could renegotiate payments under PBLs with flight-hour bands that have been crossed. We assume a fixed cost of renegotiating a crossed contract. Following renegotiation, we assume the new price would reflect the full savings in variable costs due to reduced flight hours, as specified in the baseline model. In each case, we recalculate the percentage of costs that are fixed with regard to flight hours.

Review of baseline model of fixed costs of AVDLRs

The baseline model we use was developed in [6] and is given by

$$C = C_{F,NAVSUP} + C_{F,NADEP} + p_T (A_F + A_V)$$

The total cost of AVDLRs, C, is decomposed into the fixed cost of operating the supply system, $C_{F,NAVSUP}$; the fixed cost of the Navy's

16. PBLs cover both AVDLR and consumable items. For the purposes of calibrating the model, we assume two-thirds of the cost of the PBL covers AVDLRs and one-third consumables. These represent the approximate distribution of overall FHP costs between AVDLRs and consumables.

aviation depots, $C_{F,NADEP}$; and the direct costs of the AVDLRs, where A_F represents the fixed number of repairs required independent of flight hours, and A_V represents the number of repairs that vary with flight hours. The average price per repair is given by p_T. The baseline values for the parameters, as estimated in [6], are reproduced in table 6. Total fixed cost in the baseline model is $C_{F,NAVSUP} + C_{F,NADEP} + p_T A_F$ = $367.7 million and represents about 17 percent of the total AVDLR budget.

Table 6. Baseline values of parameters, from [6]

	Parameter	Definition	Baseline value ($millions FY09)
(1)	C	Total AVDLR cost	$2,180
(2)	$C_{f,\ NAVSUP}$	FHP share of fixed cost of NAVSUP operations	242
(3)	$C_{f,\ NADEP}$	FHP share of fixed cost of depot	70
(4)	$C_{PBL(fixed)}$	Cost of fixed PBLs	na
(5)	P_t	Cost per AVDLR	$.0124
(6)	A_F	Fixed AVDLR replacements	4,493 units
(7)	A_v	Variable AVDLR replacements	146,152 units
(8)	$P_t\ A_F$	Fixed AVDLR cost (5)*(6)	$55.7
(9)	$P_t\ A_v$	Variable AVDLR cost (5)*(7)	$1,812.3
(10)	$C_{renegotiate}$	Fixed PBL renegotiation cost	na
(11)	$C_{PBL(variable)}$	Variable PBL cost	na
(12)	Total fixed cost	(2)+(3)+(8)	$367.7
(13)	Total cost	(1)	$2,180
	Percent fixed cost	(12)/(13)	16.9%

Accounting for PBLs priced per flight hour or demand

Our first step in modifying the baseline model is to account for PBLs that have payments that vary with flight hours or demand. These are the auxiliary power unit (APU) PBLs, which together amount to \$24.9 million annually.[17] We assume that by switching to this PBL arrangement, the Navy shifts some of its fixed cost of supply operations to the contractor. However, we assume the depot performing the repair does not change with the switch to PBL, so the Navy realizes no savings in depot overhead. We shift a total of \$24.9 million in costs (the value of the PBL) out of $C_{F,NAVSUP}$, $p_T A_F$, and $p_T A_V$ (in proportion to their values in the baseline model) and into a new category of variable PBL costs, $C_{PBL(variable)}$. Table 7 illustrates the calculations and shows the net impact on the percentage of costs that are fixed, a net decline of about 0.2 percentage points.

Table 7. Accounting for variable PBLs

	Parameter	Baseline value (\$millions FY09)	Adjustment	Final value
(1)	C	\$2,180		\$2,180
(2)	$C_{f,\ NAVSUP}$	\$242	-\$2.9	\$239.1
(3)	$C_{f,\ NADEP}$	\$70		\$70
(4)	$C_{PBL(fixed)}$	0		\$0
(5)	P_t	\$.0124		
(6)	A_F	4,493 units		
(7)	A_v	146,152 units		
(8)	$P_t\ A_F$	\$55.7	-\$0.7	\$55.1
(9)	$P_t\ A_v$	\$1,812.3	-\$21.4	\$1,790.9
(10)	$C_{renegotiate}$	0		
(11)	$C_{PBL(variable)}$	0	+\$24.9	\$24.9
(12)	Total fixed cost	\$367.7		\$364.2
(13)	Total cost	\$2,180		\$2,180
	Percent fixed cost	16.9%		16.7%

17. The power-by-the-hour engine contracts (totaling \$146.4 million in 2009) and the common tires PBL (worth \$12.1 million in 2009) are also priced per flight hour or per demand. We exclude them from this example because they are funded from budget lines other than FHP-AVDLR. The engines are funded from the aviation depot maintenance account, and the common tires, though still within the FHP, are consumables.

Accounting for PBLs with flight-hour bands

The total value in FY 2009 under PBLs specifying fixed payments within target bands of flight hours or demands was \$1,002.9 million. Apportioning this amount between AVDLRs and consumables using the overall approximate budget proportions of two-thirds and one-third yields an estimated \$668.6 million in AVDLR funding under PBL. To account for the effect of these PBLs on fixed costs, we apply the same method as in the previous section. We shift a total of \$668.6 million in costs out of $C_{F,NAVSUP}$, $p_T A_F$, and $p_T A_V$ (again, in proportion to their three respective values in the baseline model) and into a new category of variable costs, $C_{PBL(fixed)}$. Table 8 illustrates the calculations and shows the net impact on fixed costs, now calculated as $C_{F,NAVSUP} + C_{F,NADEP} + p_T A_F + C_{PBL(fixed)}$ = \$938.5 million, or an increase to about 43 percent of total cost.

Table 8. Accounting for fixed PBLs, assuming flight hours executed at targeted level

	Parameter	Baseline value ($millions FY09)	Adjustment	Final value
(1)	C	\$2,180		\$2,180
(2)	$C_{f,\ NAVSUP}$	\$239.1	-\$76.7	\$162.4
(3)	$C_{f,\ NADEP}$	\$70		\$70
(4)	$C_{PBL(fixed)}$	\$0	+\$668.6	\$668.6
(5)	P_t	\$.0124		
(6)	A_F	4,493 units		
(7)	A_v	146,152 units		
(8)	$P_t\ A_F$	\$55.1	-\$17.7	\$37.4
(9)	$P_t\ A_v$	\$1,790.9	-\$574.3	\$1,216.6
(10)	$C_{renegotiate}$			
(11)	$C_{PBL(variable)}$	\$24.9		\$24.9
(12)	Total fixed cost	\$364.2		\$938.5
(13)	Total cost	\$2,180		\$2,180
	Percent fixed cost	16.7%		43%

Given these estimates, a 1-percent cut in flight hours would save only 0.6 percent of the AVDLR budget.[18] Equivalently, absorbing a cut of 1 percent to the overall budget would require a 1.7-percent cut in flight hours.

Accounting for crossed flight-hour bands and renegotiation

Most PBL contracts contain a fixed price within a specified range of flight hours. If flight hours are reduced below the lower band, the PBL contract can be renegotiated. In this sense, the costs of these PBL contracts are fixed only for small (within-band) changes in flight hours. To account for this feature of PBL contracts, in this section, we calculate the reduction in fixed-cost percentage when flight hours are reduced by 5 percent and 10 percent, respectively. We use information about the actual bands specified in the PBL contracts.

In table 9, we begin with the final values in table 8 and calculate new baseline values for all the parameters recategorizing any fixed PBLs whose bands would be crossed by a 5-percent decline in flight hours. In table 10, we repeat the exercise assuming a 10-percent across-the-board cut in flight hours. As shown in figure 6, 5- and 10-percent declines in flight hours would result in the renegotiation of about 21 and 61 percent, respectively, of the value under fixed-price PBLs. We shift these values out of the $C_{PBL(fixed)}$ category and back into $C_{F,NAVSUP}$, p_T A_F, and p_T A_V (once again, in proportion to their three respective values in the baseline model).

We assume there is a fixed cost to renegotiate these PBLs of 2 percent of the value to be renegotiated, denoted $C_{renegotiate}$. This fixed cost would capture any time or resources spent by relevant officials (e.g., program officers, contracting officers, and legal advisers) simply to reach a new contractual agreement. The particular value for this fixed cost is not critical, so long as it is below the expected savings from renegotiation. In the rightmost column of each table, we

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18. Total savings are estimated as 1 percent of the total variable costs in the rightmost column of lines (9) and (11) of table 8. We assume changes in flight hours drive proportionate changes in variable demands.

then recalculate variable costs assuming a flight-hour decrease. Comparing the two rightmost cells of line (13) in table 9, we see that a 5-percent reduction in flight hours saves $68.1 million, or 3.1 percent of the total AVDLR budget. Comparing the two rightmost cells of line (13) in table 10 shows that a 10-percent flight-hour reduction saves $159.2 million, or 7.2 percent of the overall budget.

Table 9. Accounting for fixed PBLs, 5-percent reduction in flight hours

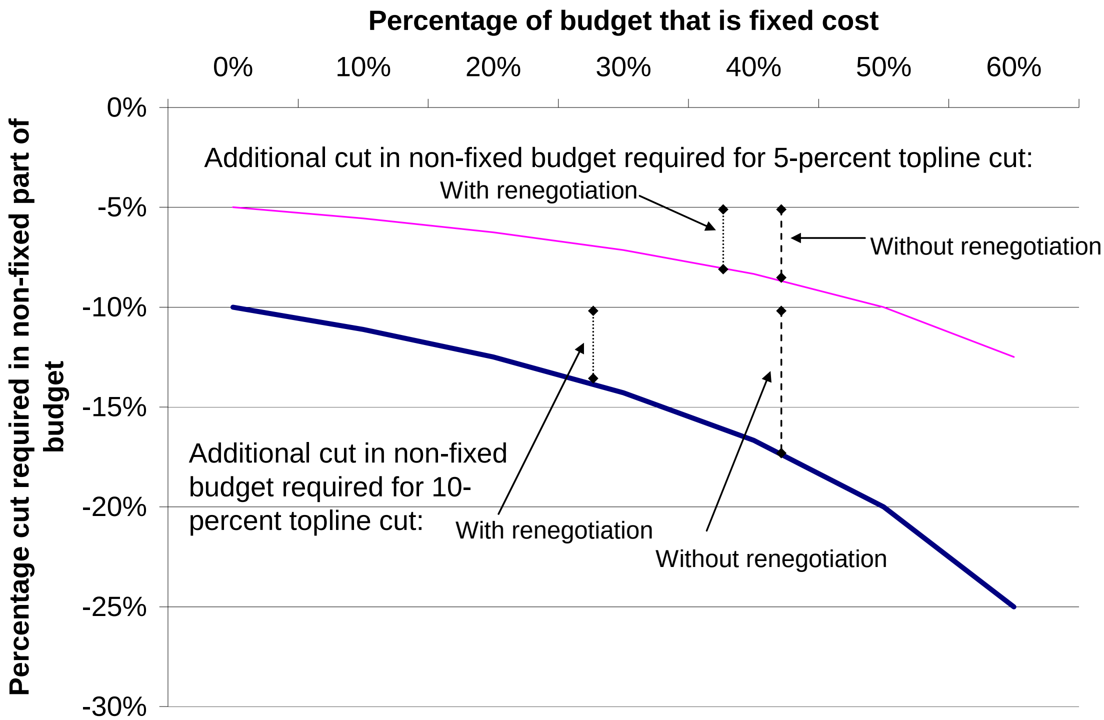
	Parameter	Baseline value ($millions FY09)	Adjustment to baseline	New baseline value	Cost assuming 5-percent flight-hour cut and renegotiation
(1)	C	$2,180	+$2.8	$2,182.8	$2,114.7
(2)	$C_{f,\ NAVSUP}$	$162.4	+$16.2	$178.6	$178.6
(3)	$C_{f,\ NADEP}$	$70		$70	$70
(4)	$C_{PBL(fixed)}$	$668.6	-$140.4	$528.2	$528.2
(5)	P_t	$.0124			
(6)	A_F	4,493 units			
(7)	A_v	146,152 units			
(8)	$P_t\ A_F$	$37.4	+$3.7	$41.1	$41.1
(9)	$P_t\ A_v$	$1,216.6	+$120.6	$1,337.2	$1,270.3
(10)	$C_{renegotiate}$		+$2.8	$2.8	$2.8
(11)	$C_{PBL(variable)}$	$24.9		$24.9	$23.7
(12)	Total fixed cost	$938.5		$820.7	$820.7
(13)	Total cost	$2,180		$2,182.8	$2,114.7
	Percent fixed cost	43%		37.6%	38.8%

Table 10. Accounting for fixed PBLs, 10-percent reduction in flight hours

	Parameter	Baseline value ($millions FY09)	Adjustment to baseline	New base-line value	Cost assuming 10-percent flight-hour cut and renegotiation
(1)	C	$2,180	+$8.2	$2,188.2	$2,029
(2)	$C_{f,\ NAVSUP}$	$162.4	+$46.8	$209.2	$178.6
(3)	$C_{f,\ NADEP}$	$70		$70	$70
(4)	$C_{PBL(fixed)}$	$668.6	-$407.8	$260.8	$528.2
(5)	P_t	$.0124			
(6)	A_F	4,493 units			
(7)	A_v	146,152 units			
(8)	$P_t\ A_F$	$37.4	+$10.8	$48.2	$41.1
(9)	$P_t\ A_v$	$1,216.6	+$350.3	$1,566.9	$1,270.3
(10)	$C_{renegotiate}$		+$8.2	$8.2	$2.8
(11)	$C_{PBL(variable)}$	$24.9		$24.9	$22.4
(12)	Total fixed cost	$938.5		$596.3	$596.3
(13)	Total cost	$2,180		$2,188.2	$2,029
	Percent fixed cost	43%		27.3%	29.4%

To capture the effect of the "must-pay" bill on the rest of the budget, we calculate how much must be cut from the non-fixed part of the budget in order to absorb a given overall percentage budget cut, as shown in figure 7. The figure illustrates the effect of allowing for renegotiation. If the PBLs with crossed flight-hour bands are not renegotiated, a 10-percent cut in the overall budget would have to be absorbed by a 17-percent cut in non-PBL, non-fixed budget items. With renegotiation, some part of this overall budget cut can be absorbed by a lower payment in a renegotiated PBL, requiring only a 13- to 14-percent cut in non-PBL, non-fixed budget items.

Figure 7. Impact of fixed-cost share on remaining budget



It is important to keep in mind that these calculations reflect the accommodation of overall budget changes within the AVDLR budget only. In practice, a given overall, topline budget cut may be absorbed by other parts of the FHP or even by other Naval Aviation Enterprise accounts. To the extent that these other accounts contain variable costs, they will need to absorb a disproportionate share of a given cut. However, as we increase the budget base, the relative percentage of the budget that is fixed declines (represented by the horizontal axis in figure 7). This means that the disparity in budget cuts required diminishes as well.

Conclusions

Looking ahead, we can apply the results of this study to project the effects of PBLs on future support requirements. It appears that, to date, aviation PBLs overall have not increased cost when compared with traditional support. The statistical precision of this estimate may be improved as we accumulate longer histories of NIINs under PBLs. The data suggest that there has been broad, above-inflation cost growth in all (PBL and non-PBL) items, but this growth has been lower among PBL-supported items. PBLs appear to yield the largest savings on those items that cost the Navy less to support.

When we estimate savings separately for PBLs at the component level, the sub-system level, and the system level, we find PBLs at the component level are associated with the largest savings. PBLs at the sub-system level account for a majority of PBLs in our sample but do not yield statistically significant savings. We estimate system-level PBLs savings of 10 percent.

We can use the models in this study to estimate the potential cost and readiness impact of switching to traditional support and/or contracting for a lower level of service, as measured by higher NMCS time. The estimates from the overall relative cost model suggest modest potential savings from a drop in level of service. We estimate that a 10-percent increase in NMCS hours per demand would result in a 1-percent drop in cost.

The choice to expand the use of PBLs must be made on a case-by-case basis (as it is currently done). The results in this study suggest that there may not be much difference in cost between PBL and traditional support for individual items that account for the largest share of repair expenditures. Where the larger savings for PBLs seem to lie is among items accounting for a smaller share of total expenditure. We have also found quite robust results that PBLs have led to improved readiness metrics.

Finally, in this study, we were able to look most carefully at impacts of PBLs within the Navy's AVDLR infrastructure. Future research may be able to use more detailed, TMS-specific historical data in other budget areas important for aviation maintenance—such as military personnel and procurement—to determine whether PBLs have had any effect in these areas.

Appendix A: Estimation model details

In this appendix we present additional technical details on the derivation of the estimation model used in this study, which for convenience is restated here.

$$\ln(c_{ijt}) = \alpha_{ij} + \beta \ln(FH_{jt} / AC_{jt}) + \gamma \ln(AC_{jt}) + \lambda(NMCS_{ijt} / D_{ijt}) + \delta PBL_{ijt} + \varepsilon_{ijt}$$

We begin with equation (1), which specifies the real cost K_{ijt} of a PBL part (NIIN) i on TMS j during time t, as a function of a scaling factor A_{ij}, flight hours (FH), NMCS time per demand D for that part, and whether that part is covered under a PBL in period t.

$$(1)\quad K_{ijt}^{PBL} = A_{ij} FH_{jt}^{\kappa_1} e^{\lambda(NMCS_{ijt} / D_{ijt}) + \delta PBL_{ijt}} \nu_{ijt}$$

This functional form allows flight hours to influence cost non-linearly (the linear case would correspond to an estimate of κ_1=1.) The choice of an exponential functional form for the NMCS per demand and PBL explanatory variables allows the dependent variable (cost) to take positive values even when these latter explanatory variables take values of zero. It also assumes that a constant change in the explanatory variable results in the same proportional change in the dependent variable.

For each TMS j, we define non-PBL NIINs to be all parts on TMS j that were never covered by a PBL. We use equation (2) to calculate the total real cost of all non-PBL NIINs (indexed by n) on TMS j in time t corresponding to each PBL NIIN i on the same TMS j during the same time period t.

$$(2)\quad K_{ijt}^{\sim PBL} = \sum_n K_{njt}^{\sim PBL}$$

In equation (3), we assume the total cost for all non-PBL parts is a function of a scaling factor B_{ij} and flight hours. Specifying different parameters for the exponents on flight hours (κ_1 and κ_2 in equations (1) and (3), respectively) allows for flight hours to affect PBL and non-PBL parts differently. The terms ν_{ijt} and η_{ijt} in equations (1) and (3) respectively are assumed to be log-normally distributed, independent random errors with location parameter equal to zero.

(3) $K_{ijt}^{\sim PBL} = B_{ij} FH_{jt}^{\kappa_2} \eta_{ijt}$

We then construct our dependent variable of interest (the cost of a PBL part relative to the cost of its reference group of non-PBL parts) by dividing equation (1) by equation (3). We obtain

(4) $\dfrac{K_{ijt}^{PBL}}{K_{ijt}^{\sim PBL}} = \dfrac{A_{ij}}{B_{ij}} FH_{jt}^{(\kappa_1 - \kappa_2)} e^{\lambda(NMCS_{ijt}/D_{ijt}) + \delta PBL_{ijt}} \dfrac{\nu_{ijt}}{\eta_{ijt}}$

We rename variables using the following definitions:

$c_{ijt} = \dfrac{K_{ijt}^{PBL}}{K_{ijt}^{\sim PBL}} \quad \theta_{ij} = \dfrac{A_{ij}}{B_{ij}} \quad \omega_{ijt} = \dfrac{\nu_{ijt}}{\eta_{ijt}}$

$\rho = \kappa_1 - \kappa_2$

Using the renamed variables and taking logarithms of both sides of the equation, we rewrite (4) as

(5) $\ln(c_{ijt}) = \ln(\theta_{ij}) + \rho \ln(FH_{jt}) + \lambda(NMCS_{ijt} / D_{ijt}) + \delta PBL_{ijt} + \ln(\omega_{ijt})$

Finally we decompose total flight hours into the product of flying intensity (flight hours per aircraft) and number of aircraft (AC). We allow these explanatory variables to have distinct effects on cost, captured by the parameters β and γ, which need not equal ρ. We rename the remaining variables using the following definitions:

$\alpha_{ij} = \ln(\theta_{ij}) \qquad \varepsilon_{ijt} = \ln(\omega_{ijt})$

Substituting these definitions and decomposing the flight hours term yields our estimation equation.

$$\ln(c_{ijt}) = \alpha_{ij} + \beta \ln(FH_{jt} / AC_{jt}) + \gamma \ln(AC_{jt}) + \lambda(NMCS_{ijt} / D_{ijt}) + \delta PBL_{ijt} + \varepsilon_{ijt}$$

The log-normality and independence of ν_{ijt} and η_{ijt} imply that ω_{ijt} is also log-normal and ε_{ijt} has a normal distribution. The equation can be estimated using fixed-effects ordinary least squares.

Appendix B: Summary statistics

Table 11 lists the groups of NIIN-TMS pairs that comprised our analysis sample. Some PBL contracts are associated with a single group, but others are associated with multiple groups because NIIN-TMSs were added over time.

Table 11. Summary statistics of estimation sample, by NIIN-TMS group (1of 3)

NIIN-TMS group name	Initial PBL award	Number of NIINs in group	Total cost, pre-PBL ($FY09)	Total cost, post-PBL ($FY09)	Weight in sample
AV-8B HISS Group 1	Jun 07	380	$72,354,586	$48,366,720	4.1%
AV-8B HISS Group 2	Jun 08	408	$39,064,270	$18,596,733	2.0%
AV-8B HISS Group 3	Dec 08	220	$6,067,475	$3,706,101	0.3%
Common ALQ-126B	Feb 05	123	$16,252,773	$21,408,229	1.3%
Common AMC	Apr 08	7	$11,614,379	$10,754,198	0.7%
Common ARC-210	Jan 01	19	$3,026,979	$8,972,997	0.4%
Common CAINS	Jul 07	2	$2,754,408	$2,108,427	0.2%
Common TIRES	Feb 01	24	$3,033,270	$8,424,855	0.4%
EA-6B Hydraulics	Jan 05	110	$21,129,349	$20,753,761	1.4%
Engines F404	Jul 03	94	$8,065,889	$9,442,942	0.6%
Engines F414 Fleet Support	Nov 04	849	$7,781,556	$59,020,263	2.1%
Engines T-700 Rotors	Sep 04	17	$101,314,803	$119,652,264	7.6%
F/A-18 FIRST	May 01	14994	$757,649	$64,042,456	1.2%
F/A-18 HUD-DDI (F-18)	Sep 03	211	$96,702,565	$122,325,308	7.5%
F/A-18 SMS (AV-8B)	Sep 99	120	$180,827	$626,191	0.0%
F/A-18 SMS (F-18)	Sep 99	262	$1,870,575	$5,639,421	0.2%
F/A-18 SMUG (F-18)	Mar 06	32	$6,106,294	$12,850,476	0.7%
H-46 Phase I	Feb 06	26	$19,137,293	$13,899,857	1.1%
H-53 Phase I	Feb 06	26	$72,547,368	$81,633,826	5.2%
H-60 FLIR	Sep 03	3	$37,639,713	$75,840,097	3.9%
H-60 Tip to Tail	Dec 03	465	$149,224,997	$215,357,856	12.5%
H-60 Tip to Tail (Avionics)	May 02	61	$3,344,519	$7,400,892	0.4%
H-60 Tip to Tail (Dynamic Components)	Feb 03	34	$86,237,486	$164,347,272	8.5%
H-60 Tip to Tail Phase 2	Jun 06	436	$316,973,782	$349,487,845	22.8%
H-60 Tip to Tail Phase 2A	Sep 07	273	$27,957,527	$19,087,785	1.5%

Table 11. Summary statistics of estimation sample, by NIIN-TMS group (1of 3)

NIIN-TMS group name	Initial PBL award	Number of NIINs in group	Total cost, pre-PBL ($FY09)	Total cost, post-PBL ($FY09)	Weight in sample
P-3 APS-137	Dec 06	16	$45,808,622	$60,516,526	3.3%
P-3 APU (C-130)	Feb 02	11	$4,310,049	$7,336,731	0.4%
P-3 APU (C-2)	Jun 00	8	$1,383,026	$1,175,225	0.1%
P-3 APU (F-18 E/F)	Feb 02	7	$196,989	$3,358,796	0.1%
P-3 APU (F-18/A-D)	Jun 00	22	$7,863,690	$13,042,485	0.7%
P-3 APU (H-46)	Oct 03	8	$20,238,284	$19,167,061	1.3%
P-3 APU (H-53)	Oct 03	8	$16,006,029	$17,683,201	1.2%
P-3 APU (P-3)	Jun 00	29	$11,154,492	$16,255,205	0.9%
P-3 APU (S-3)	Jun 00	18	$4,537,561	$9,941,229	0.5%
P-3 EDC	Oct 03	15	$37,673,476	$25,272,780	2.2%
P-3 Main Fuel Controls (F404)	Jun 04	18	$31,502,529	$45,876,179	2.6%
Support Equipment CASS 09 (CASS CSP)	Jun 01	306	$24,173	$94,699	0.0%
Support Equipment CASS 09 (Hi Power)	Jul 03	526		$5,063	0.0%
Total			$1,401,947,971	$1,683,471,952	

The number of NIINs covered under the PBL includes all NIINs, even those that experienced zero demand during our sample period. Costs for the pre- and post-PBL periods are in constant FY 2009 dollars. The sample weights are those that were used in our weighted regressions. The aggregate weight for the various groups under the H-60 tip-to-tail PBLs is about 44 percent, by far the largest.

We also calculated total flight hours and average number of aircraft for all TMSs covered in each NIIN-TMS group. The summary statistics are listed in table 12. Of note are the growth in the fleet of F/A-18 E and F TMSs reflected in the pre-PBL vs. post-PBL flight hours and average aircraft columns of the F/A-18 FIRST group. Comparing pre- to post-PBL periods for the NIIN-TMS items in our sample, there are lower flight hours and flight hours per aircraft in the post-PBL period.

Table 12. Summary statistics of estimation sample, by NIIN-TMS group (2 of 3)

NIIN-TMS group name	Total flight hours pre-PBL	Total flight hours post-PBL	Average aircraft pre-PBL	Average aircraft post-PBL	Total flight-hours per aircraft pre-PBL	Total flight-hours per aircraft post-PBL
AV-8B HISS Group 1	110,700	87,468	123.2	113.4	898.5	771.3
AV-8B HISS Group 2	72,767	58,808	116	113.1	627.3	519.8
AV-8B HISS Group 3	51,951	46,816	114	112.9	455.7	414.6
Common ALQ-126B	412,821	334,664	226.7	174.4	1681.3	1850.3
Common AMC	121,633	144,930	131.2	154.8	915.5	923.3
Common ARC-210	65,439	77,486	120.1	118.4	694.6	791.8
Common CAINS	127,506	151,261	100.4	122.1	1271.9	1220.3
Common TIRES	73,269	87,168	99.1	102	790.5	968.6
EA-6B Hydraulics	189,131	220,626	104.3	93.5	1814	2360.2
Engines F404	321,651	259,298	205.9	159.7	1537.6	1589.7
Engines F414 Fleet Support	68,164	312,762	31.9	137.7	2126.2	2255.3
Engines T-700 Rotors	181,966	191,182	95.5	99.5	1999.8	1989.5
F/A-18 FIRST	7,047	40,090	8.8	39.8	838	1005
F/A-18 HUD-DDI (F-18)	270,018	263,406	167.9	151.9	1589.9	1677.9
F/A-18 SMS (AV-8B)	20,978	22,841	143	130.2	146.7	175.5
F/A-18 SMS (F-18)	74,042	67,615	243.1	221.7	302.7	295.8
F/A-18 SMUG (F-18)	110,816	262,889	65.9	147.8	1673.4	1766.4
H-46 Phase I	154,292	191,434	146.8	174.9	1106.1	1094.8
H-53 Phase I	95,826	100,870	88	96.7	1196.7	1095.8
H-60 FLIR	161,930	143,185	84.5	76.7	1889.3	1690.3
H-60 Tip to Tail	228,565	221,461	114.1	110	2034.9	1933
H-60 Tip to Tail (Avionics)	200,970	217,298	149.8	145.4	1341.7	1495.6
H-60 Tip to Tail (Dynamic Components)	144,282	146,478	87.7	85.4	1595.6	1662.4
H-60 Tip to Tail Phase 2	150,271	137,149	85.2	84.3	1745.8	1588.3
H-60 Tip to Tail Phase 2A	92,351	82,845	76.1	73.6	1179	1117.3
P-3 APS-137	277,043	253,894	183.9	143.7	1506.4	1766.4
P-3 APU (C-130)	85,804	37,550	54.1	27.2	1570.3	1637.9
P-3 APU (C-2)	23,225	16,307	38.5	29	585.1	562.3
P-3 APU (F-18 E/F)	13,242	155,864	12.7	126.2	1063.9	1255.7
P-3 APU (F-18/A-D)	119,877	113,515	224.2	203.2	531.8	552.4
P-3 APU (H-46)	108,136	165,379	91.7	137.9	1583.4	1157
P-3 APU (H-53)	81,782	117,780	79.6	98.2	1056.6	1222.4
P-3 APU (P-3)	146,353	151,134	177.4	177.4	830.9	877.2
P-3 APU (S-3)	74,433	74,979	116.9	114.7	646.7	662.9
P-3 EDC	489,065	333,612	193.7	169.4	2524.9	1969.2
P-3 Main Fuel Controls (F404)	327,570	338,921	177	174.1	1858	1904.7

Table 12. Summary statistics of estimation sample, by NIIN-TMS group (2 of 3)

NIIN-TMS group name	Total flight hours pre-PBL	Total flight hours post-PBL	Average aircraft pre-PBL	Average aircraft post-PBL	Total flight-hours per aircraft pre-PBL	Total flight-hours per aircraft post-PBL
Support Equipment CASS 09 (CASS CSP)	61,344	68,810	79.6	85.4	763.7	789.2
Support Equipment CASS 09 (Hi Power)		194,178		99.8		1945.7
Average	220,688	151,097	114.5	111.8	1900.0	1336.6

We also used the AV3M database to collect data on the number of demands (repairs or replacements), as well as on NMCS rates for NIIN-TMS pairs in each group. Table 13 provides summary statistics for these variables.

Table 13. Summary statistics of estimation sample, by NIIN-TMS group (3 of 3)

NIIN-TMS group name	Average NMCS hours per demand pre-PBL	Average NMCS hours per demand post-PBL	Average demands pre-PBL	Average demands post-PBL
AV-8B HISS Group 1	522.3	243.3	29.6	18.1
AV-8B HISS Group 2	660.6	62.2	18.4	10.6
AV-8B HISS Group 3	926.2	17.3	15.8	12.2
Common ALQ-126B	32.7	7.6	13.8	11.6
Common AMC	1280.2	1069.7	48.9	30.2
Common ARC-210	295.8	212.2	24	56.1
Common CAINS	1223.4	1151.7	37.8	62
Common TIRES	17.1	0.2	257.3	324.2
EA-6B Hydraulics	1848.0	1121.6	31.3	32.6
Engines F404	180.2	144.5	30.9	35.9
Engines F414 Fleet Support	757.3	1114.0	10.5	29.8
Engines T-700 Rotors	0.0	0.5	48.1	70.7
F/A-18 FIRST	964.8	809.3	1.6	5.7
F/A-18 HUD-DDI (F-18)	451.1	397.1	20.9	22.3
F/A-18 SMS (AV-8B)	78.2	71.6	2.4	3.9
F/A-18 SMS (F-18)	1145.0	1159.8	4.4	4.9
F/A-18 SMUG (F-18)	613.6	454.5	16.5	36.9
H-46 Phase I	1351.4	1173.9	68.4	75
H-53 Phase I	968.5	443.3	36.3	46.9
H-60 FLIR	0.8	0.0	56.4	103.7
H-60 Tip to Tail	502.9	251.0	32.7	38.5
H-60 Tip to Tail (Avionics)	20.7	4.2	10.3	15.6

Table 13. Summary statistics of estimation sample, by NIIN-TMS group (3 of 3)

NIIN-TMS group name	Average NMCS hours per demand pre-PBL	Average NMCS hours per demand post-PBL	Average demands pre-PBL	Average demands post-PBL
H-60 Tip to Tail (Dynamic Components)	1487.5	934.9	30.5	22.6
H-60 Tip to Tail Phase 2	435.8	183.1	35.8	30.5
H-60 Tip to Tail Phase 2A	77.5	73.2	12.9	11.7
P-3 APS-137	2.4	0.0	68.2	55.7
P-3 APU (C-130)	12.7	9.2	8.5	11.7
P-3 APU (C-2)	31.1	24.4	5.1	11.3
P-3 APU (F-18 E/F)	2181.7	620.0	3	7.6
P-3 APU (F-18/A-D)	1739.7	929.1	11.1	11.3
P-3 APU (H-46)	619.7	657.3	50	53
P-3 APU (H-53)	1257.0	517.1	37.1	30.5
P-3 APU (P-3)	2.1	2.5	29.8	34.7
P-3 APU (S-3)	588.9	168.1	14.8	23.2
P-3 EDC	119.2	206.4	108.9	97.1
P-3 Main Fuel Controls (F404)	1252.4	1425.6	58.2	72.6
Support Equipment CASS 09 (CASS CSP)	0.0	0.0	1.3	1
Support Equipment CASS 09 (Hi Power)		0.0		1
Average	587.4	435.3	24.5	28

With few exceptions, we observe (often substantial) declines in NMCS time per demand after the PBL takes effect.

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Appendix C: PBL regression results

In this section, we present the detailed results of our regressions analyzing the effect of PBLs on cost and readiness.

PBL effects on overall cost

Table 14 summarizes our findings on cost. The dependent variable in column (1) is the natural logarithm of real *absolute* cost of PBL items, whereas it is the natural logarithm of real *relative* cost of PBL to non-PBL items in columns (2) and (3). The results in columns (1) and (3) represent weighted regressions, where the weights are given by the total expenditures over the entire sample. The coefficient estimates for the PBL indicator variable can be interpreted approximately as the percentage effect of the post-PBL period on the relevant dependent variable.[1] For instance, in column (1) the estimated coefficient of 0.197 for the PBL indicator implies that PBL items cost 21.8 percent more during the PBL period than during the pre-PBL period. The estimates of -0.242 and -0.127 in columns (2) and (3), respectively, mean that PBL items cost 21.5 percent and 11.9 percent less, respectively, relative to non-PBL items, in the post-PBL period than in the pre-PBL period.

1. If the coefficient estimate on the PBL indicator is r, the true percentage change is calculated as e^r - 1. For values of r close to zero, this can be approximated by r.

Table 14. Overall cost and relative cost regression results

	(1)	(2)	(3)
Dependent variable	Ln(Cost)	Ln(Relative cost)	Ln(Relative cost)
Weighted/unweighted	weighted	unweighted	weighted
PBL indicator	0.197	-0.242	-0.127
	(2.58)*	(10.86)**	(1.61)
Log (Flight hours per aircraft)	2.103	0.627	1.374
	(6.30)**	(4.34)**	(3.50)**
Log (Number of aircraft)	1.256	-0.617	-0.103
	(10.13)**	(10.56)**	(0.77)
NMCS hours per demand	-0.0002	-0.0001	-0.0002
	(4.90)**	(5.47)**	(4.84)**
Constant	-6.540	-9.468	-13.173
	(2.65)**	(8.45)**	(4.41)**
Observations	8580	8580	8580
Number of NIIN-TMS items	5963	5963	5963
R-squared	0.26	0.15	0.07

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Effects on cost, by type of PBL

We estimated the model separately for component-level, sub-system-level, and system-level PBLs. The results in table 15 suggest that the largest savings have been realized from component-level PBLs, with estimated savings of 17.7 percent, as indicated by the coefficient of -0.195 in column (1). This estimate is statistically significant at the 1-percent level. Sub-system-level PBLs had no statistically discernible effect on cost relative to non-PBL items, as indicated by the statistically insignificant estimate of -0.072 in column (2). This group of PBLs accounts for the majority of items in our overall sample and may be driving the overall results. System-level PBLs are associated with savings of 10.4 percent, though this estimate is significant only at the 90-percent level.

Table 15. Overall relative demand and cost regression results, by PBL type

	(1)	(2)	(3)
PBL type	Component-level	Sub-system level	System-level
Dependent variable	Ln(Relative cost)	Ln(Relative cost)	Ln(Relative cost)
Weighted/unweighted	weighted	weighted	weighted
PBL indicator	-0.195	-0.072	-0.110
	(3.23)**	(0.41)	(1.83)
Log (Flight hours per aircraft)	-0.742	0.517	3.411
	(1.59)**	(1.05)	(4.65)**
Log (Number of aircraft)	0.408	-0.266	-0.483
	(2.09)*	(1.94)	(2.47)*
NMCS hours per demand	-0.0003	-0.0001	-0.0004
	(3.64)**	(3.26)**	(6.22)**
Constant	-0.954	-6.59	-26.055
	(0.29)	(1.90)	(4.55)**
Observations	901	4497	3193
Number of NIIN-TMS items	567	3265	2138
R-squared	0.22	0.03	0.24

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Effects on cost, by total expenditure quintile

We further explored the difference in savings from PBLs by grouping the NIIN-TMS items individually into five quintiles according to total expenditures for them in our sample. The top quintile contained NIIN-TMSs from various component- and system-level PBLs, and accounted for more than 93 percent of all the expenditures in our sample. Table 16 contains the results of this analysis. We use the estimate reported in column (1) to calculate that the estimated relative savings due to PBL for the highest-cost group was 11.8 percent, but this was not statistically significant. However, for the remaining quintiles, relative savings ranged from 17.6 percent to 38.4 percent, and all estimates were significant.

Table 16. Relative cost regression results, by expenditure quintile

	(1)	(2)	(3)	(4)	(5)
Expenditure quintile	Highest-cost group	Second highest-cost group	Third highest-cost group	Fourth highest-cost group	Lowest-cost group
Dependent variable	Ln(Relative cost)	Ln(Relative cost)	Ln(Relative cost)	Ln(Relative cost)	Ln(Relative cost)
Weighted/ unweighted	weighted	weighted	weighted	weighted	weighted
PBL indicator	-0.125	-0.225	-0.194	-0.317	-0.485
	(1.50)	(4.78)**	(3.24)**	(5.35)**	(5.54)**
Log (Flight hours per aircraft)	1.394	1.266	0.376	-0.557	-0.775
	(3.12)**	(3.67)**	(1.01)	(1.54)	(2.55)*
Log (Number of aircraft)	-0.044	-0.426	-0.733	-0.969	-1.300
	(0.29)	(4.11)**	(5.59)**	(7.40)**	(6.20)**
NMCS hours per demand	-0.0002	-0.0001	-0.0001	-0.0001	0.0000
	(4.53)**	(3.97)**	(4.61)**	(1.93)	(1.68)
Constant	-13.331	-13.832	-7.325	-0.577	1.382
	(3.97)**	(5.48)**	(2.71)**	(0.20)	(0.52)
Observations	1743	1608	1478	1315	1061
Number of NIIN-TMS items	917	919	917	916	919
R-squared	0.07	0.13	0.13	0.25	0.44

Robust t statistics in parentheses

* significant at 5%; ** significant at 1%

PBL effects on logistics performance metrics

Table 17 shows the results of our examination of PBLs' effects on readiness metrics. We see that PBLs are associated with robust declines in NMCS hours per demand and wait time per demand. We examined what might be occurring with reliability by examining effects on total demands, controlling for flight hours. This can be thought of as a variant of a common reliability metric, mean flight hours between demand (MFHBD). We see that, unweighted by cost, relative demands are lower (column (4)), but, where weighted by cost, relative demands are unaffected by PBLs (column (5)). Average NMCS hours per demand among items with positive NMCS hours in the pre-PBL period were approximately 1,500, suggesting that PBLs reduced these by 15 percent. Average wait time among items with non-zero wait time in the pre-PBL period was 2,500 hours per demand, suggesting wait times improved by 42 percent as a result of PBLs.

Table 17. Logistics performance metrics regression results

	(1)	(2)	(3)	(4)	(5)
Dependent variable	NMCS hours per demand	Wait time per demand	Ln(Absolute demand)	Ln(Relative demand)	Ln(Relative demand)
Weighted/unweighted	weighted	weighted	weighted	unweighted	weighted
PBL indicator	-215.652	-1,063.561	0.065	-0.047	-0.004
	(6.46)**	(2.03)*	(0.86)	(2.71)**	(0.05)
Log (Flight hours per aircraft)	682.729	-627.219	1.764	0.367	0.301
	(3.03)**	(0.33)	(6.17)**	(3.65)**	(1.23)
Log (Number of aircraft)	301.181	1,379.639	1.279	-0.309	0.074
	(2.80)**	(1.86)	(12.82)**	(8.15)**	(0.77)
NMCS hours per demand			-0.0002	-0.0001	-0.0002
			(4.26)**	(5.66)**	(4.60)**
Constant	-5,671.415	131.289	-14.432	-8.531	-7.609
	(3.38)**	(0.01)	(7.01)**	(10.74)**	(4.14)**
Observations	10538	10538	8584	8594	8584
Number of NIIN-TMS items	5963	5963	5963	5973	5963
R-squared	0.07	0.02	0.25	0.06	0.03
Robust t statistics in parentheses					

Effects of PBL contract characteristics on cost

Table 18 shows the results of our unweighted regressions examining the effects of various contract terms and characteristics on the relative cost of PBL to non-PBL items. We considered the effect of each term by including it as an additional explanatory variable in the baseline model. Column (1) shows the estimates from the unweighted regression. Column (2) contains the estimates from the regression in which parts are weighted in proportion to total expenditure. PBLs that were awarded competitively are estimated to yield greater savings. The magnitude of the effect is between 19 and 45 percent (obtained by converting the coefficient estimates of -0.21 and -0.59 to percentage terms). Longer contracts are associated with slightly larger savings, though this result is statistically significant only in the weighted regression. Each additional TMS supported is associated with 3.1-percent higher cost. This effect is also statistically significant only in the weighted regression.

We included variables for the flight-hour bands specified in the PBL contract. We measure the lower band as the percentage below the targeted flight hours for which the PBL payment is fixed. Thus, higher numbers indicate a larger band. The coefficient estimates for the lower and upper bands are consistent with our expectations, though they are statistically insignificant.

Table 18. Contract characteristics, regression results

	(1)	(2)
Dependent variable	Ln(Relative cost)	Ln(Relative cost)
Weighted/unweighted	unweighted	weighted
PBL indicator	0.440	0.304
	(1.95)	(1.07)
Log (Flight hours per aircraft)	0.658	1.946
	(3.50)**	(3.83)**
Log (Number of aircraft)	-0.596	-0.118
	(10.45)**	(0.91)
NMCS hours per demand	-0.0001	-0.0002
	(5.24)**	(5.61)**
Lower band (Percentage below target FH)	-0.102	-0.032
	(1.28)	(0.20)

Table 18. Contract characteristics, regression results

	(1)	(2)
Dependent variable	Ln(Relative cost)	Ln(Relative cost)
Weighted/unweighted	unweighted	weighted
Upper band (percentage above target FH)	0.071	0.011
	(0.89)	(0.07)
Length of contract (years)	-0.013	-0.028
	(1.71)	(2.05)*
Number of metrics in contract	-0.039	0.001
	(1.59)	(0.04)
Competition indicator	-0.21	-0.59
	(2.09)*	(3.20)**
Number of TMSs covered	0.011	0.031
	(1.88)	(2.18)*
Constant	-9.797	-17.332
	(6.89)**	(4.49)**
Observations	8579	8579
Number of NIIN-TMS items	5962	5962
R-squared	0.17	0.09

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Effects of renewal PBLs on cost

We present the results of the regressions with PBL renewals as an explanatory variable in table 19. Renewals boost the average savings rate by 12.4 percent according to the unweighted regression in column (1). They have a statistically insignificant effect on relative cost in the weighted regression in column (2). In neither case do we find support for the proposition that costs increase at the time of renewal.

Table 19. Effect of renewal PBLs on cost, regression results

	(1)	(2)
Dependent variable	Ln(Relative cost)	Ln(Relative cost)
Weighted/unweighted	unweighted	weighted
PBL indicator	-0.178	-0.074
	(6.74)**	(1.22)
Renewal indicator	-0.132	-0.092
	(3.06)**	(0.65)
Log (Flight hours per aircraft)	0.622	1.335
	(4.29)**	(3.52)**
Log (Number of aircraft)	-0.602	-0.076
	(10.37)**	(0.52)
NMCS hours per demand	-0.0001	-0.0002
	(5.35)**	(4.97)**
Constant	-9.494	-13.009
	(8.47)**	(4.50)**
Observations	8580	8580
Number of NIIN-TMS items	5963	5963
R-squared	0.15	0.07

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

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Glossary

APU	auxiliary power unit
AV3M	aviation material maintenance management
AVDLR	aviation depot level repairable
BCA	business case analysis
CASS	consolidated aviation support system
CONUS	continental United States
ECP	engineering change proposal
FLIR	forward looking infrared
HISS	Harrier integrated supply support
HUD/DDI	head-up display / digital display indicator
ILS	integrated logistics support
LECP	logistics engineering change proposal
NAVAIR	Naval Air Systems Command
NAVICP	Naval Inventory Control Point
NIIN	National Item Identification Number
NRFI	not ready for issue
OCONUS	outside of continental United States
PBL	performance based logistics
PBTH	power-by-the-hour
TMS	type-model-series

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