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The Relative Costs and Benefits of Multi-year Procurement Strategies

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A. Introduction

Multi-year procurement (MYP) contracts allow the purchase of more than one fiscal year's quantity in a single contract. The government contracts to purchase the entire multi-year quantity at the beginning of the contract, for delivery over several years. In contrast, in single-year procurement (SYP) contracts, the government agrees to purchase one fiscal year's quantity at a time, but may have options to purchase additional years on the same contract. An important distinction is that the government can choose not to exercise its options or sign a follow-on SYP contract, while the cancellation of an MYP contract within the contract period imposes penalties on the government.

The commonly accepted advantage of using MYP contracts is the lower price to the government, which in this paper is called the *MYP discount*. This discount represents the cost reduction from the procurement of a similar number of units and delivery schedule using a series of SYP contracts. Buying several years' quantity at once allows the contractor to implement production improvements such as placing larger orders (usually referred to as economic order quantities, or EOQs), gaining efficiencies from more steady plans and labor force requirements, and reducing the administrative burden associated with writing multiple proposals and negotiating multiple contracts.[1] The MYP discount is explicitly estimated in the "business case analysis" that is required to justify the acquisition strategy before the Congress. This discount can be viewed as a discrete "step-down" against the more gradual price improvement curve (PIC) reductions that arise through continuous improvements in the production process.[2]

From the government's perspective, the MYP discount can be offset by other costs. The primary analyses documented in this paper examined the government's opportunity costs of using an MYP contract; these additional costs are mainly associated with reduced government flexibility. The MYP obligates the government to multiple future year purchases, imposing an opportunity cost in the form of larger contract termination liability (TL). This cost is not typically computed as an expense, although it is a real

[1] Sometimes the full value of reduced administrative burden is not captured in the MYP discount.

[2] The term "price improvement curve" is used when referring to the effect of the learning process on prices in lieu of cost.

opportunity cost since it limits the government's future procurement choices. This liability is like any contingent claim; it is the same for a commercial bank that issues letters of credit, which must hold regulatory capital in reserve against future draw downs.

There are other benefits that are not commonly explicitly recognized but have effects on the value of the contract to both parties. For the contractor, an MYP contract (1) reduces its expected revenue volatility, and (2) provides more incentive, from so-called *regulatory lag*, to make cost-reducing investments that result in additional profit. The first item appears to only benefit the contractor. The Institute for Defense Analyses (IDA) has already reported that the value of revenue volatility reduction could, in some cases be worth about 1 to 2 percentage points of fee. This is significant given that the MYP discount is usually less than 10 percent of cost. Estimating the value of the regulatory lag effects of MYP contracting is the subject of additional analyses documented in the paper.

Another aspect of limiting flexibility is associated with the regulatory lag effect; MYPs prevent the government from renegotiating the successive lots. On one hand, by not negotiating lower prices with every lot, regulatory lag sets in and the contractor has the incentive to invest even more effort and capital into lowering the cost. On the other hand, the government may be relinquishing too much re-pricing flexibility to regulatory lag and not reaping any price benefit.

Because MYPs impose constraints on future government action, these contracts must meet statutorily established criteria in order to be used. The basic criteria for judging whether an MYP contract is suitable for a particular procurement are:

- Stable requirements
- Stable funding
- Stable design
- Realistic estimates of contract cost and savings
- Promote national security

In a successful MYP contract, both the government and contractor would gain—the cost of producing the object being procured is reduced, and this savings can be divided between the government and the contractor by reducing contract price by less than the full amount of savings.

B. Problem Statement

What are the costs and benefits to the government of entering into an MYP compared with buying the same goods or services through an equivalent number of SYPs? The benefits are the MYP discount and the potential to greater savings induced by the regulatory lag relative to the lot-by-lot negotiations that can occur with an SYP. Other than the recurring cost of the procured item, the added costs are for financing the larger procurement quantity, the opportunity cost associated with the larger TL, and the delay or loss of opportunity to re-price procurements.

The financing cost change is mainly associated with the larger advance procurement (AP) required for the MYP. This is due partly to the increased dollar amount of the MYP contract relative to a single SYP contract. It is also due to the additional capital needed to fund the work in process to produce in larger EOQs.

Similar to financing cost, the larger opportunity cost comes from the greater nominal TL with an MYP relative to the single SYP. Not only is the TL larger with an MYP, it is larger earlier in the overall procurement, which leads to a higher present value of cost. Estimating this cost using government interest rates means that this cost is low relative to substantial savings that could be attained with an MYP, given the present low interest rates and relatively flat yield curve.

In acquisitions where the buyer is making regular (e.g., annual) procurements, *regulatory lag* is created by the time gap between the vintage of cost observations by the regulator (e.g., contracting agent) and the negotiation of the price for the next procurement. The longer the lag, the more time the contractor has to retain profits from actions to reduce the recurring cost. In complex weapon systems procurements, lags exist when contract negotiations are annual for firm fixed-price (FFP) contracts that take up to three years to execute. A five-year MYP would potentially result in a lag of five or more years.

For example, F-22 contract negotiations were usually conducted based on cost data from two lots prior to the lot being negotiated—Lot 6 negotiations were initiated using data from Lot 4 experience.[3] Given the three-year MYP contract initiated at Lot 7, any additional cost reductions in Lots 6 through 9 would have led directly to additional profits, without any feedback on prices charged for the later lots.

The cost and benefits of these two unique aspects of MYP contracting (the opportunity costs to the government and the regulatory lag effects) will be examined with two distinct analytical approaches. The first approach is a simple cost-benefit analysis (CBA)—a simple discounted cash flow analysis to estimate the cost and benefits to the government of using an MYP compared with buying an equivalent quantity using a series of SYP contracts. This model will include the cost effects of the additional AP and TL, the benefit of the MYP discount, and the cost of less re-pricing flexibility.

The second approach is the investment incentive analysis (IIA). It is also a discounted cash flow analysis that examines the incentive effect of longer regulatory lag

[3] J. Richard Nelson et al., "F-22A Multiyear Procurement Business Case Analysis" (FOUO), IDA Paper P-4116 (Alexandria, VA: Institute for Defense Analyses, 2006).

inherent in MYP contracts. Is there a benefit to the government from this characteristic of MYP contracts? How much additional value accrues to the contractor? In the model developed to answer this question, F-22 data is used to establish a baseline case which served both as a calibration point and as a point of departure for sensitivity analyses, including a range of counterfactual scenarios.

C. Modeling Approach

Both the CBA and IIA models consist of the government's cash flows associated with SYP, MYP, or both types of contracts. The design is intended to capture aspects of costs to the government that would differentiate between SYP and MYP contracts. The models apply most generally to discrete products purchased through Federal Acquisition Regulation (FAR) part 15-type contracts, i.e., not commercial, and not to most services contracts.[4]

Four key aspects of costs are captured: the lot cost of the procured product, the MYP discount, the cost of the TL, and the contractor's investment to reduce costs. The remainder of this section will describe the main elements of the model and the analyses that will be performed with it.

1. Event Horizon

The base case event horizon for the CBA is 15 annual lot buys using SYP contracts in one case (base SYP) and five annual lot buys using SYP contracts followed two five-lot-buy multiyear procurements (base MYP). The production lead time is the same for both cases since the annual production rate is assumed to be about the same for both cases. One lot buy is assumed to take three calendar years to deliver, while one five-lot buy is assumed to take seven years to execute. The IIA uses two even horizons: the first is shortened to nine lots so that the analysis can be calibrated to F-22 budget costs; and for the second, the horizon is extended to an equivalent of 15 SYP lots.

2. Discount Rates, Opportunity Cost of Capital, and Inflation

The discount rates reflecting the government's time value of money are selected or interpolated from the treasury yield curve according to the term of the overall production program.[5] Therefore, both the base SYP and MYP cases have the same 15-year discount

[4] The model could apply to services whose attributes and the cost per unit of service were easy to measure.

[5] Alternatively, the rates are provided in the Office of Management and Budget Circular A-94 Appendix C, which can be accessed at: http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c. The yield curve shows the yield, or interest rate, of debt as a function of different maturity dates from the date of issuance.

rate, which is interpolated from the 10- and 20-year rates. The discount rate depends on the decision to buy the production program, not on whether to buy in single- or multiple-year lots. The term of the opportunity cost of capital associated with the TL is a shorter term rate than the discount rate, as it is linked to the term of the TL and is thus set to the contract length. These rates are accessed from the Federal Reserve of St. Louis (FRED) data service and Excel plug-in.[6]

In order to test the effect of the cost of capital on the relative cost of an MYP, a model is used to generate a term structure of rates. This analysis is needed due to the difference in durations between the cost of risk between short-term SYP and long-term MYP contracts. While the present yield curve is flat due to the rate easing by the Federal Reserve, historically the yield curve can be quite steep. This steepness will affect the relative cost of capital for longer-term contracts with high TLs.

A simple one-factor model is used to simulate the term structure based on one-month rates. The model terms are derived from calibration using US Treasury debt.[7] The requirement in this analysis is to get a rough approximation for the rough term structure of rates that may arise in the future. The analysis does not require the accuracy or precision of a more sophisticated multi-term model that might be desired for pricing securities.

The two interest rate regimes are tied to two inflation rate regimes. The present low-interest rate regime has low inflation, while the high-interest rate regime has higher inflation. The inflation rate used is the "gross domestic product implicit price deflator" series extracted from FRED.[8] The high-inflation rate is the nominal average annual rate from 1970 to 2005, while the low-inflation rate is the rate from 2011 over 2010.

For the SYP scenario, the contract price is escalated each year by the average annual inflation rate after the effects of learning are applied. The MYP price is assumed to reflect the projected inflation rate applied to each year of production occurring under the contract. Consequently, the two inflation regimes are not expected to have a unique cost effect on either the MYP or SYP scenarios. However, inflation rates must be considered when using nominal interest rates.

3. Contract Execution Rates and Termination Liability

The contract execution rates (in terms of percentage completion) are assumed to progress according to the progress payments (shown as a percentage of total contract

[6] The Federal Reserve Bank of St. Louis Economic Data Add-in 1.0 (Beta). The tool can be downloaded from http://research.stlouisfed.org/fred-addin.

[7] Data reference.

[8] The actual data series is from the US Department of Commerce, Bureau of Economic Analysis.

value paid) listed in Table 1. The payment rates are the contract completion rates adjusted for the customary performance payment rate of 90 percent of the costs incurred.[9] The contract progress rates are derived by minimizing the volatility of the total annual production activity at the plant, given the lead times for the SYP and MYP are 3 years and 7 years, respectively.

Table 1. Contract Execution Rate and Associated Termination Liability

	SYP		MYP	
	Payments	**TL**	**Payments**	**TL**
AP	3%		3%	
Year 1	32%	34%	15%	40%
Year 2	70%	24%	27%	37%
Year 3	100%	0%	41%	35%
Year 4			55%	30%
Year 5			69%	26%
Year 6			83%	3%
Year 7			100%	0%

The SYP is completed faster, but the MYP is five times larger, requiring more AP and a higher TL.[10] The same AP percentage of the contract value, which is highly dependent on the specific commodity procured, is used in both the SYP and MYP cases. The specific rate in Table 1 is based on the weighted average AP cost as a percentage of total contract value for a selection of MYP contracts.[11] The AP for either an MYP or SYP contract can be up to 20 percent of the contract value for commodities with very long lead times.[12]

Table 1 also lists the TL as a function of the annual contract progress. The TL schedule is adopted from the Financial Management Regulation (FMR) relating to the payment process for Foreign Military Sales (FMS). Generally the TL is estimated by the program office with the contractor's input and only becomes an actual cost if the contract is terminated. For FMS transactions, the US government invoices the foreign government in advance of payments to the amount of the TL. The TL in this case is based on the "normal administrative and procurement lead times for the type of commodity procured." The FMR publishes schedules of the TL "to support contracts for aircraft and related

[9] The customary rate for progress payments is up to 80 percent.

[10] The AP budget includes so-called EOQ funding.

[11] Nelson et al., IDA Paper P-4116.

[12] DoD Financial Management Regulation Volume 15, Chapter 4 "CASH MANAGEMENT," 24–26.

equipment" by contract "lead time" (a.k.a. total execution period) and month completed.[13]

The cost of carrying the TL is a better measure of the relative opportunity cost of the MYP since it allows for the fact that the government still retains the right to cancel for convenience. The loss in flexibility is not the full cost of the MYP since the government still has the right to cancel the contract for convenience (or for default). Furthermore, programs are required to fund the TL and not the full MYP amount.[14]

The *cancellation ceiling*, a separate concept associated with contract termination, is specifically associated with MYP contracts. This contingent liability does not in all cases appear to require to be covered with obligated funding. The liability is associated with incremental contract costs that would be incurred if the procurements were not made under the MYP terms, e.g., EOQ cost reductions. For example, all or part of the MYP discount might be reversed if fewer units were procured than the MYP contract specified.

4. Unit Cost Modeling Assumptions and Implications

The two different analytical approaches use different unit cost assumptions. In the CBA base case, a notional procurement is assumed with a T_1 unit cost of $10. In this case, the analysis is illustrative and is only indirectly verified with empirical data. With the IIA, the model is calibrated to the F-22 unit cost. This allows the estimation of potential benefits of the incentive effect.

The contractor is assumed to discover and implement cost savings reductions that cumulatively lower the unit cost of production (a.k.a. learning). The effect on the unit cost is to follow a simple LC, where production cost declines as successive units are produced. It is also assumed that the government negotiates the cost of future lot buys lower based on revealed savings as the actual production cost of earlier lot buys are reported. For the CBA, the assumption is a one-year lag between reported costs and the current lot being negotiated. For example, a lot buy negotiation for the year 2014 would have actual cost data from the lot buy negotiated in 2012. For the IIA, the assumption was for a two-year lag based on information specific to the F-22 program. The assumptions are independent of whether an SYP or MYP contract is used, since it is assumed that the negotiators can receive cost data on partially completed lot buys. The difference for the MYP is that the government must wait longer to use the information in negotiating the next contract.

[13] DoD Financial Management Regulation Volume 15, Chapter 4 "CASH MANAGEMENT," 24–26.

[14] Warren R. Abel et al., "Impact of Enhanced Multiyear Procurement on Defense Acquisition—A Status Report," MSP #27 AY 82/83 (Washington, DC: Industrial College of the Armed Forces, May 1983).

There are two distinct learning processes: *ex ante* learning is the adjustment to the negotiated contract price representing expected contractor cost innovations; and *ex post* learning is the adjustment to the negotiated contract price representing unexpected savings from previous contracts revealed to the government through cost reporting. Ex ante learning may force the contractor to achieve a lower cost in order to make a profit on the contract. It is also considered exogenous learning (determined outside of the IIA model). Ex post learning affords the contractor higher short-term profits until it is reported to the government and incorporated into future prices. It is also considered endogenous learning (determined within the IIA model).

The IIA uses an optimization framework in which the contractor adjusts investment behavior to maximize the net present value (NPV) of a series of contracts. The pricing rules take into account the observed F-22 lag between contract execution and the availability of cost data for future contract price negotiation. The model distinguishes between lot-to-lot cost reductions due to exogenous learning phenomena and endogenous learning that requires contractor effort and investment.

In the CBA, the learning rates are assumed; the underlying contract price reduction mechanisms are not endogenous to the model. Through the course of the production program, both ex ante and ex post reductions could be contributing to lower cost. However, the learning effects and other cost reductions in this analysis are weighted towards *ex post* improvements, since they are a function of the cumulative units lagged by one year.

It is reasonable to expect that the government would anticipate the contractor achieving greater endogenous learning in an MYP than with the same number of SYP contracts. This is due to the longer investment planning horizon afforded through the MYP that should lower the contractor's hurdle rate for cost reduction investments. The government may anticipate some of this learning and incorporate it into the MYP discount. The MYP discount may include not only the cost reductions due to EOQ production but also other expected process improvements that would otherwise not be adopted under SYP contracting.

The main goal of both model analyses is to test whether the cost reduction incentive design inherent in an MYP scheme is effective. MYP contracts are not intended to protect the government against random exogenous cost increases. Neither the CBA nor IIA will explore the cost implications of systemic risks such as adverse changes in inflation or to the production quantity. These effects are real, but in some cases can be managed by contracting tools such as an economic pricing adjustment clause.

One perceived benefit of the MYP may be to prevent the government from exercising its propensity for making design changes to the procured item that could lead to cost growth. While this is axiomatically true, it is not the purpose of the MYP, since one of the five legal criteria for using an MYP is for the design to be stable. Another perceived benefit of the MYP may be the view that it locks in the quantity procured. Since the MYP is funded annually, the government clearly retains substantial flexibility towards making adjustments throughout the contract life. Because the factors driving cost increases are highly uncertain, they are not included in this analysis.

5. Rate Effects

It is possible that an MYP discount partially reflects efficiencies afforded through a faster production rate. The production rate is an important determinant in the unit cost of a procured item. However, neither the CBA nor the IIA explicitly include rate as an input. The difficulty with incorporating a rate effect is the uncertainty associated with the level of other activities at the plant. This is important for determining whether overhead will change as the production rate of the procured item changes. For example, if the production rate decreases to below a minimum efficient level on the MYP contract, other plant activities may increase and take a higher overhead allocation.

6. Model Summary

The key parameters of the CBA are listed in Section D. The CBA compares two scenarios: the full procurement program using SYP contracts, and the same number of units procured through four SYP contracts followed by two MYPs. This model construction is aimed at assessing the combined cost and benefits of using the MYP contract: the MYP discount of 10 percent, the incremental cost of the AP and TL, and the loss in re-pricing flexibility. The analysis will examine the effect of the discount relative to other factors that can affect the cost of the MYP compared to the SYP series. The purpose of the analysis will be to gauge the minimum MYP discount that is needed to justify its risks and costs.

Appendix A describes the model specification and parameter values for the IIA. The model captures changes in contractor investment behavior over different SYP and MYP scenarios as the contractor maximizes its NPV of the series of contracts. The parameter values are determined by calibrating the model to the F-22 costs. Unlike the CBA, parameter values are fixed for all scenarios.

D. Findings Part 1: MYP Cost-Benefit Analysis

The next sections will present the analytical findings by discussing the effects of the important model parameters. The model outputs are the results of two scenario analyses, representing two strategies to procure the same number of items. Within each scenario, other operating parameters will be varied. The base scenario (A) is an all-SYP production program versus scenario B—a short series of SYPs followed by two five-year MYP contracts. Scenario B captures the most common way serial procurements would occur, particularly given the five justification criteria. The default MYP will be for an equivalent of five SYPs, although the length of the MYP will also be examined.

The procurement operating parameters are summarized in Table 2. The article procured has a first unit (T_1) cost of $10 at the beginning of the initial production year with a 15 percent fee, so that the first SYP lot contract price is $115. Each year, the government has a need for a lot quantity of 10 units. The actual number of lots is a model variable ranging from 5 to 30. The standard MYP includes 5 standard lots. As stated earlier, the MYP and the SYP contracts are negotiated with the actual production cost of the penultimate production year or lot, respectively.

Table 2. The CBA Procurement Operating Parameters

Model Parameter	Scenario A and B Settings
T_1 Cost/First Contract Price	$10/$115
Number of units/lot	10
Total number of units procured	150
Number of lots/MYP	5
Contract execution time (years)	3 for SYP and 7 for MYP
Baseline LC slope	90% for MYP and SYP scenarios
Scenario A: number of lots	15 SYP lots
Scenario B: acquisition strategy	5 SYP lots then 2 sequential MYP contracts

Within each scenario, the interest, MYP savings, and LC rates are varied. This will include a mix of enumerated cases and where appropriate sensitivity analysis will be used to provide contract decision or design guidelines. The body of this report will focus on the two base case scenarios. Figure 1, sometimes called a cost waterfall chart, shows the cascade of cost differences between scenarios A and B, where the cost of A is normalized to 100.[15] The figure is used to break out the main cost differences between the SYP and MYP contracting scenarios. Each chart in the figure can be best understood by starting with the left-most bar, labeled “SYP w/o Learning,” and then adding or subtracting the boxes to its right. Each box to the right is the incremental difference, due to each cost driver, between the bar labeled “SYP w/o Learning” and one labeled “MYP w/o Learning.” Isolating the cost effects depends on the order in which they are introduced into the model. The nature of the cost drivers behind each box will be discussed in the following sections (note that the order of the sections is the same as that used in Figure 1).

[15] This type of chart is often used to decompose the differences between the budgeted cost and the actual cost.

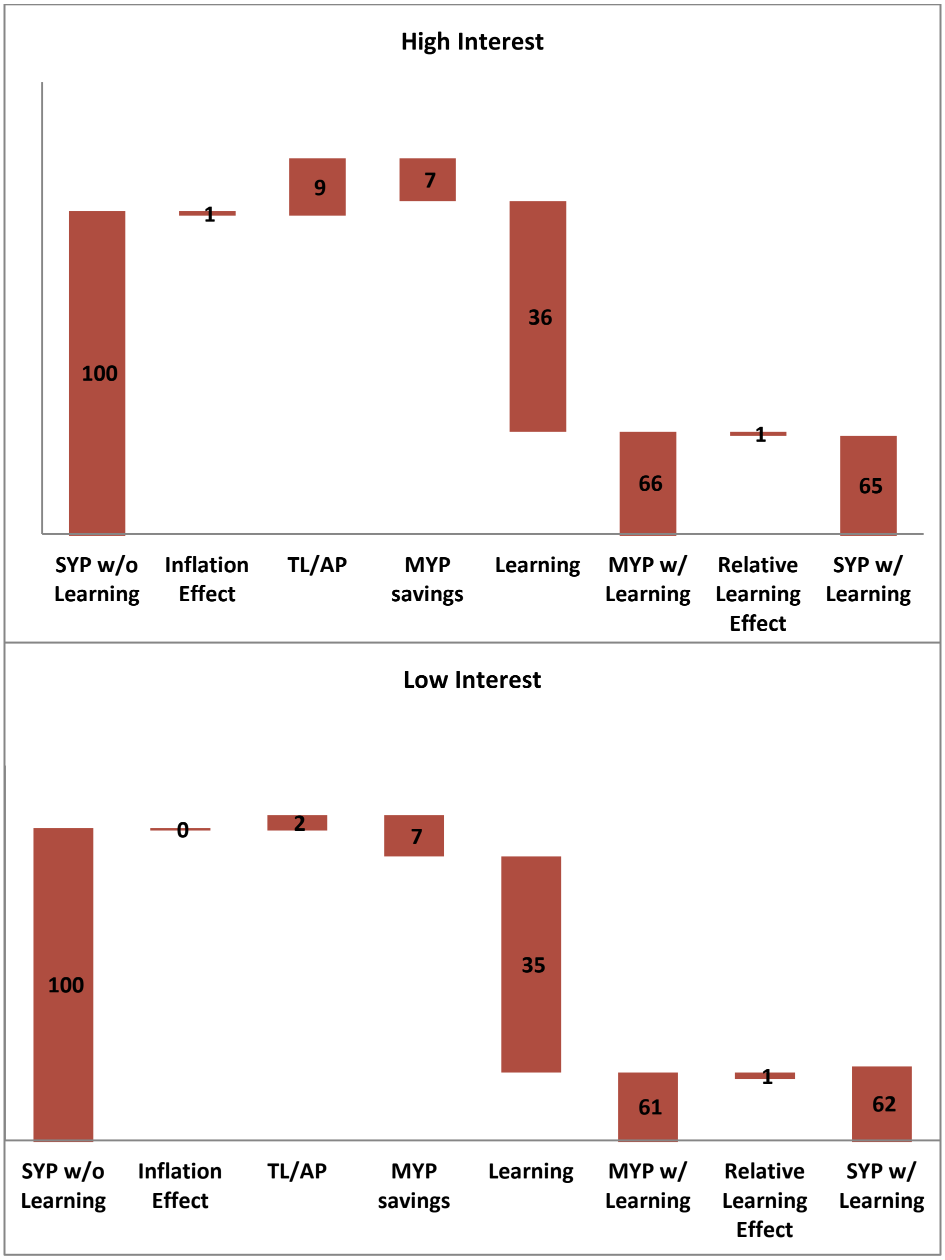

Figure 1. Waterfall Charts Comparing Base Case SYP and MYP Scenarios

1. The Effect of Inflation and Interest Rates

An MYP is priced to reflect the contractor's and DoD's inflation forecasts. Deviations from the forecast will affect the cost performance of the MYP contract. If inflation turns out to be lower than the forecast, the contractor will earn higher profits; conversely, it will have lower profits if actual inflation is higher. Often, contractors hedge inflation in long-term contracts with an economic pricing adjustment clause so that the government retains the inflation risk.

The main purpose of different inflation assumptions in the model is to make systemic cost growth consistent with interest rate assumptions and discount rates. All three rates are varied consistently, i.e., high interest rates are usually contemporaneous with high inflation. Inflation is not observed in Figure 1 to have a large discriminating effect on the two scenarios because it is assumed that actual inflation is the same as the forecast—i.e., this is not a performance simulation model.

2. The Cost Effects of the AP, Progress Rate, and TL

To isolate the cost of the TL and AP, the MYP savings is set to zero while learning is set to 100 percent (no learning). The larger MYP contract value, relative to a single SYP contract, is reflected in larger AP and TL requirements. AP is set to 3 percent of the contract value for both the SYP and MYP cases.[16] Although the AP rate is the same for both procurement types, the MYP has a higher cost on a present value basis because the contract value is five times as large. With scenario A, the AP payments are spread out over five fiscal years, whereas for an MYP they are concentrated in the first year.

The MYP progress rate is assumed to be more gradual than the progress of the SYP. The level of plant activity remains roughly the same: the size of the MYP contract offsets its slower progress rate. Progress rates are not observed to have a large effect on the present value of cost. This condition is not necessarily realistic. A plant has other scheduling inputs and ways it can allocate fixed costs that it can use to improve efficiencies. The opposite may also be true—actual government requirements for units may not allow the most efficient production scheduling.

The TL acts like a reserve requirement on a contingent liability such as a letter of credit or liability coverage (i.e., insurance). The government's ultimate liability if the contract is completed is the contract price. But since the government is able to cancel the contract for convenience at any time, its actual liability at any given time is the calculated TL. Programs typically must fund the annual MYP appropriation to include the TL but not necessarily the cancellation ceiling. Holding a reserve has an opportunity cost, since the funds may not be used to pay for beneficial alternatives. This cost is estimated using the market cost of capital for the government, i.e., the Treasury note rate.

Both procurement scenarios carry a TL and incur an opportunity cost. The TL for the MYP is both larger in amount and has a higher present value cost since it is

[16] Nelson et al., IDA Paper P-4116.

concentrated towards the beginning of the contract. The effect of the timing of the cash flows becomes apparent with discounting.

Interest rates and discount rates are correlated with inflation rates in the model. Thus, as mentioned in the last section, higher discount rates tend to cancel out the effects of higher inflation. But higher interest rates do have a significant negative effect on the value of an MYP. This is due to the migration of cash flows earlier in the overall procurement strategy (higher present value effect) and also the higher opportunity cost of the TL. The upfront payments and large TL put MYP at a funding disadvantage to SYP contracting. Although the AP and TL costs are only a few percent of the contract value (see Figure 1), it means that the MYP discount afforded to a contract is less than what it appears nominally.

3. The MYP Discount

The decision to use the MYP strategy requires a business case analysis to justify that the lower costs are worth tying up the government's budgeting flexibility. The MYP is priced at a discount relative to buying the same quantity of units through SYP contracts. In this analysis, the discount represents reductions that are strictly due to the existence of an MYP, which gives the contractor enough planning certainty to produce in more efficient lot sizes or to allow it to justify investing in more efficient processes.[17]

The discount does not include any of the normal anticipated learning—this effect should be in the baseline SYP costs. There could be cost reductions beyond those underlying the discount or the anticipated learning. The potential to realize these incremental reductions will be analyzed in Part 2 of the findings and the IIA results.

Figure 1 shows that the value of the MYP discount in the low-interest case (bottom waterfall chart) more than offsets the incremental opportunity cost of the AP and TL. Since the MYP savings are contingent on the long-term commitment of the government to purchase units, they are directly linked to the presence of the AP and TL requirement. Consequently, in low interest rate environments, the MYP savings come at relatively low cost, while in high interest rate environments, the savings may not justify the opportunity cost of the additional AP and TL. The assumption is that the MYP discount is 10 percent, but averages to about 7 percent over the entire acquisition cycle (which includes five SYP contracts).

[17] Lower cost design changes could possibly be included, but would need to be consistent with the statutory requirement of design stability.

4. The Effect of Learning and Other Revealed Contractor Cost Reductions

Learning and other contractor-initiated cost reductions, other than those explicitly linked to the MYP business case, are analyzed in two steps. In this section, the CBA model is used to capture the relative propensity for the government to renegotiate prices as it gains new cost information. In Part 2 of the findings, the IIA model is used to explore the investment incentive effect of the MYP and to test its effectiveness with some empirical analysis.

In the CBA analysis, both procurement scenarios have the same vintage of actual production costs when the next contract is negotiated. The difference is that the frequency of price negotiations is yearly in the SYP scenario, whereas the MYP scenario has annual contract negotiations for the first six years and then only one more contract negotiation in year 10. The more contracts that are negotiated, the more opportunity the government has to use updated cost information to reduce the contract price.

In Figure 1, the learning effect is broken into two parts. The first part represents the savings associated with adding learning in the MYP contracting scenario relative to the case where that scenario has no learning—only the MYP discount. The other component of the learning effect, the bar between those labeled "MYP w/learning" and "SYP w/learning," is due to the option of capturing these effects earlier in the production program through more frequent SYP price negotiations.

Capturing these savings earlier and more frequently in the program leads to more learning being reflected in price reductions in the SYP scenario, although not enough in the low interest case to offset the MYP discount: SYP learning = 38 percent vs. net MYP reduction = 39 percent. The difference is small because, in both procurement scenarios, most of the learning occurs in the first five SYP lots. This is corroborated in Figure 2, which shows the same type of waterfall comparison as in Figure 1. except that the scenario B acquisition strategy uses three MYPs in lieu of five SYPs and two MYPs. In this case, the SYP strategy provides the government better capacity to capture incremental learning through price negotiations in the first five lot buys.

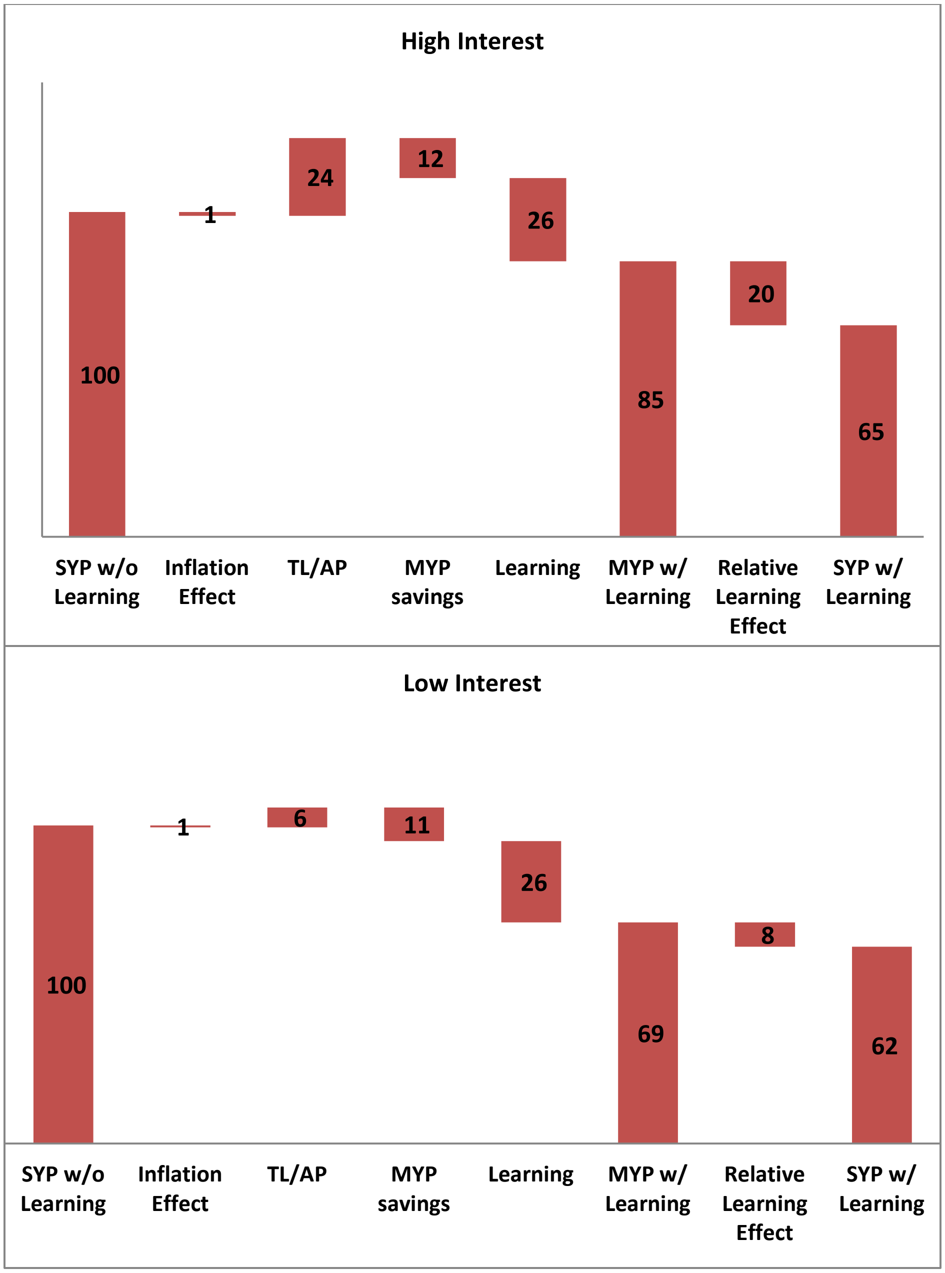

Figure 2. Waterfall Charts Comparing Base Case SYP and All-MYP (Three Five-Year MYPs) Scenarios

Excluding the investment incentive, the CBA shows that an MYP with a discount of 10 percent does not appear to reduce the average cost to the government over an equivalent SYP strategy. The analysis is generic and applies to many common acquisitions, but it is not analytically general. There are combinations of procurement operating parameters in which the MYP strategy provides better cost outcomes.

To choose between specific SYP and MYP strategies, the important decision variables are the *ex post* learning expected in a series of SYP lot buys, the *ex post* learning expected in the MYP strategy, and the MYP discount. The scenario analyses shown in Figure 1 and Figure 2 assume that the expected learning in both strategies is the same; however, contractor investment incentives would tend to result in greater year-to-year cost reductions in the MYP cases (this is the subject of the IIA analyses). Figure 3 maps the effects of three variables on the cost outcome comparison between procurement strategies A and B in the low interest rate environment. The figure maps the decider's indifference curve between scenario A (SYP only) and scenario B (SYP followed by MYP). The curve shows the required MYP discount rate for different combinations of SYP and MYP PIC. Each line represents combinations of the three variables where the government is indifferent between the two strategies.

The chart illustrates how much the MYP discount must be to make up for the lost option value of renegotiation when compared to the corresponding series of SYP contacts. For example the top curve represents the case in which the choice is between SYP and MYP acquisitions with different PICs, but the NPV for the government is equal when the MYP discount is 14 percent. At the extremes of the curve, the 14 percent discount requires the MYP case to have at least an 82 percent PIC to be equal in cost with an SYP program with a 91 percent PIC. At the other extreme of the indifference curve, an SYP with a 97 percent PIC requires the MYP to have at least a 94 percent PIC when combined with the 14 percent discount.

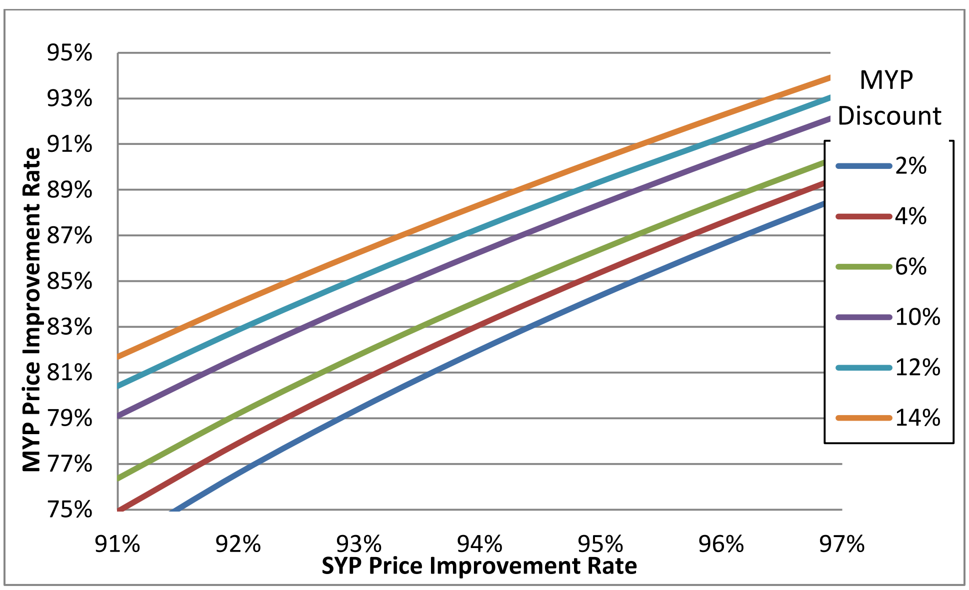

Figure 3. Comparing Minimum Required MYP PIC Slope and Discount Rate for a Given Level of SYP PIC Slope for Break-even

To use this chart requires a thorough analysis of the program production cost data and an understanding of the product and contractor. More importantly, the program and contracting activity must honestly assess its ability to discover contractor savings and to use the data to extract the savings from the price of future contracts. Many contracting activities do not collect the right kind of cost information for discovering when the contractor is making sustained reductions to recurring costs. Without the actual cost, including an accurate variance analysis, it is difficult to negotiate lower prices in a sole source cost reimbursable framework. Contractor negotiating teams have a strong incentive to project costs that are high enough to ensure future profitability. In this framework, it is very difficult, even with high quality cost data, to convince the contractor to accept a cost based on yet-to-be-realized cost reductions. Ironically, in such cases the contractor may have the incentive to continue reducing costs and enjoy increasing profitability.

5. The Number of Lots and the Effect of Pure or Mixed MYP Strategies

Figure 4 shows that the relative cost effect ranking of the SYP and MYP strategies does not change as the number of lots in a procurement program increases. The red and black curves show the normalized average unit cost under the SYP and MYP strategies, respectively. The blue curve is the difference between the red and black curves as a percentage of the SYP scenario average cost. In the low interest rate environment, the MYP strategy has lower average cost, while in the high interest rate environment, the SYP strategy has lower average cost.[18] Figure 4 shows the costs of the two base case strategies and the difference in cost as a percentage of the all-SYP strategy. Note that for five lots, the two scenarios are identical—both are SYP strategies. The left vertical axes are the normalized cost while the right axes are the savings relative to the all-SYP case. The two strategies are compared with the same overall 90 percent LC slope under the low interest rate scenario. The high interest rate scenario shows that at low lots, the MYP and SYP costs are indistinguishable, and at higher lots, the latter strategy yields lower cost. The cost spread widens as the number of lots increases, because in both cases more contracts allows for more price negotiation.

[18] In Figure 4, the MYP-based scenario assumes a 10 percent discount.

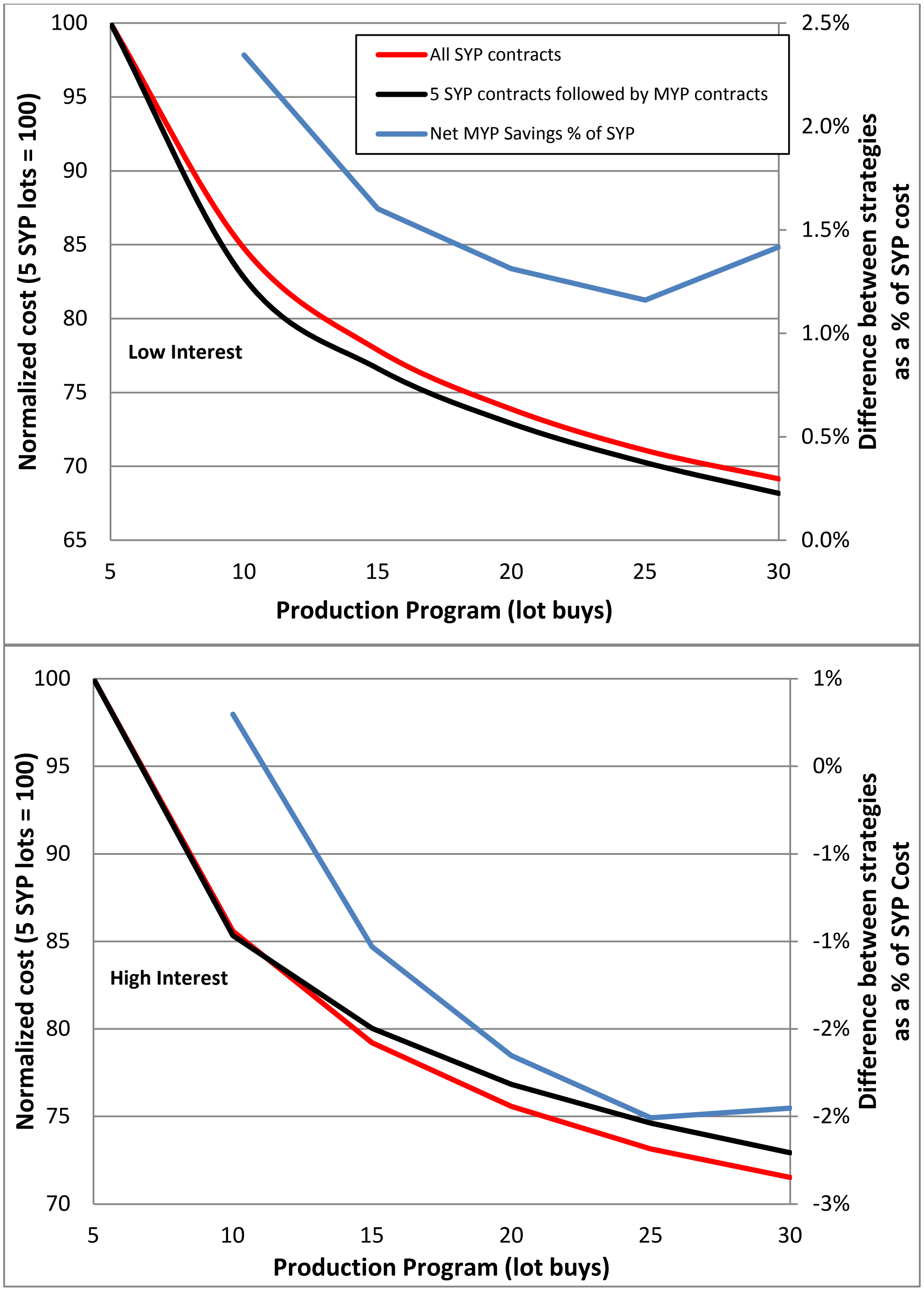

Figure 4. Relative Cost of SYP and MYP Strategies vs. Number of Program Lot Buys

The choice of where to place an MYP in a production program is an important cost driver. It is also implicitly related to the stable design requirement to justify an MYP. The first few lots in a production program are usually the low rate initial production phase, when the design has not been fully stabilized. This is also when a significant amount of learning is leading to significant cost reductions. Acquisition plans that lock up the pricing in an MYP for the early lots of production may be highly unfavorable to the government.

6. Part 1 Conclusions: MYP Cost-Benefit Analysis

The purpose of the CBA is to benchmark the potential cost effectiveness of a mixed MYP strategy (five SYP contracts, followed by two MYP contracts consisting of five lots each) relative to the same quantity and schedule purchased through a series of 15 SYP contracts. The effectiveness is examined from the perspective of the government, which seeks to buy at the lowest present value cost over the course of the production program. This analysis identified three main procurement design variables: the MYP discount, MYP learning, and SYP learning. It also identified the interest rate environment as an exogenous cost driver that is important in deciding whether to use an MYP strategy.

The MYP requires larger AP and TL in order to fund the savings derived from buying in larger quantities. The opportunity cost associated with the AP and TL is a tax on the MYP savings. In low interest rate regimes, these costs are notionally small, but in higher interest rate regimes, they can erode the entire savings. The question may remain with the reader whether the interest cost associated with borrowing the AP and TL measures the loss in flexibility. The answer may depend on who in the government is asked; government agencies may well face more difficult hurdles to raising incremental funds than reflected by the US Treasury note rate. Is a program office like a small operating division of a much larger consolidated corporation with many operating units? At the division level, the cost of capital, which could be a mandated “hurdle” rate, may be much higher than the corporate bond rate. No, the decision to use an MYP is not analogous to business unit decisions. The decision to use an MYP contract is made at the highest levels of government. MYPs limit the flexibility of the Congress to make future appropriations, and its opportunity cost of capital is the Treasury note.

Figure 4 shows that the strategy choice is not very sensitive to the size of the acquisition. Figure 3 shows that the choice *is* sensitive to the expectation for learning. If a large amount of learning is expected with an SYP strategy, then almost as much learning must be attainable with the MYP strategy in addition to the MYP discount. Although there is some tradeoff between the MYP discount and the expected realized learning from the MYP strategy, the discount most likely needs to be well in excess of 5 to 10 percent.

Consider the case in which the expected learning from the SYP strategy is 82 percent. Every percentage point in learning that is lost by using an MYP strategy requires an additional 5 percentage points of discount, in addition to a baseline of 5 percent. Less learning under an MYP strategy would most likely be due to the reduction in re-pricing that would normally occur with SYP contracts. Conversely, MYP contracts could result in greater ex post learning due to the investment incentive. This will be addressed in Part 2 of the findings.

E. Findings Part 2: MYP Investment Incentive Analysis

The investment incentive model rests on three basic premises: defense contractors view a sole source acquisition program as a protected franchise, revealed cost savings result in future contract price reductions, and future prices are based on the underlying cost. These assumptions imply that the contractor is reluctant to reduce the long-term procurement cost, absent other competitive forces, unless the reduction provides a sufficient rate of return.

Consider the decision process: the contractor has an internal cost reduction proposal that reduces the unit cost by $500 on a lot size of 1,000 units and requires a $1 million investment. The contractor would have a 50 percent return and a payback of about two years if it had claim to the savings for that long. But if the savings are revealed after one year, the contractor may be at risk for recovering its investment. Furthermore, if the contractor usually receives a 15 percent fee on cost, all future contracts with the same lot size would receive $75,000 less in fee. What might look like a great investment idea for a commercial company could create a loss for a defense contractor.

The prudent defense contractor in this situation would only invest in cost reduction projects that have rates of return exceeding 100 percent. This notion was confirmed in conversations with officials at a major defense contractor. Further confirmation came from a Lockheed Martin earnings conference call with Wall Street analysts:[19]

> **Samuel J. Pearlstein**
> **Wells Fargo Securities, LLC, Research Division**
>
> Chris, I wanted to go back to something you had said earlier in the call. You talked about $1.2 billion of overhead reduction in the last few years and on the docket for another $1.1 billion this year. I guess I'm trying to just understand, how much does it cost for you to actually accomplish that? What kind of returns do you get, and then how much of that do you actually get to keep as opposed to it ultimately going back to the customer?
>
> **Christopher Eugene Kubasik**
> **Vice Chairman, President, Chief Operating Officer, and Member of Executive Office of the Chairman**
>
> Yes, Sam. That's a great question. It varies by business area. This is pretty much the overhead reduction. A lot of this ties to some of the facility. I gave you some numbers on the facility square footage that were taken out. We do a business case and a payback for all these affordability projects that we have. And generally, they pay back within the 12- to 18-month

[19] Earnings Call Transcript, Lockheed Martin Corporation, October 24, 2012 accessed from CapitalIQ on October 31, 2012.

> cycle. So when we do something like facility consolidation, we'll be moving the cost of moving the cost of consolidating as it relates to that. Right now, we're about 50% cost plus 50% fixed price. So half goes in back to the government, if you will. The other half generally is built into our forward pricing to some degree. It really depends on the backlog mix. But the investment to get these overhead savings are [sic] not that significant and generally results in both people and capital assets as the main driver. Of course, we're focused on processes and new systems and such, but it's a pretty quick payback.

Lockheed's management is stating that they invest in projects to reduce overhead that have a 75 percent to 100 percent return on investment. They further indicate that half of the savings are retained for about two years before being revealed and forfeited to the government. The two-year lag comes from the fact that as of the end of the third quarter of 2012, Lockheed had an order backlog of about $80 billion, which is 1.7 times their annual revenue.[20] Contractors will take the initiative to reduce cost, but only if they have the prospect of retaining sufficient profitability to exceed internal hurdle rates of return.

The IIA model is designed to test whether the long regulatory lag implied by an MYP contract leads to greater cost reduction investment, lower contract cost, and lower contract prices. This was accomplished within an optimization framework, described in Appendix A, in which the contractor adjusts investment behavior to maximize the NPV of a series of FFP contracts. Investment adds to capital stock (k_t), which in turn reduces lot costs (C_t); increased k_t results in higher negotiated fees through the facilities capital mark-up (γ).

The pricing rules take into account the lag between contract execution and the availability of cost data for future contract price negotiation. The IIA model differs from the CBA in that future savings from exogenous learning (*ex ante* savings) are known by the government at the time of contract negotiation. These savings are additive to savings from investment, which are known to the government only after the fact (*ex post* savings). This is not entirely realistic, as the government may, and should try to, anticipate at least some of the savings from investment.

1. Model Calibration

The parameters of the IIA model are estimated through calibration with input variables based on data from the completed F-22 program. F-22 production consisted of a series of FFP contracts covering nine lots. The calibrated IIA model was then used to examine whether the MYP contract appears to provide the investment incentive and whether the outcome has any benefit to the government.

[20] Data extracted from CapitalIQ on January 23, 2013.

The F-22 budget data for the airframe portion of flyaway costs was used for the model calibration. The data were taken from publicly available President's Budget Submission justification books (specifically the P-5 exhibits). To convert the F-22 data to constant dollars, we used an airframe-specific weighted escalation index. Table 3 presents the data used.

Table 3. F-22 Airframe Price Data

Lot	Contracting Strategy	Quantity	Cumulative Quantity [a]	Unit Price, TY$M	Unit price, FY10$M
2001	SYP	10	27	123.5	164.2
2002	SYP	13	40	108.9	143.0
2003	SYP	21	61	98.7	124.6
2004	SYP	22	83	91.4	110.5
2005	SYP	24	107	82.8	93.3
2006 [a]	SYP	24	131	83.1	89.2
2007	MYP	20	151	84.3	88.1
2008	MYP	20	171	83.7	83.5
2009	MYP	20	191	86.1	87.1

[a] Cumulative quantity included 9 EMD and 8 production representative test aircraft; also included was a test aircraft replacement bought with RDT&E funds in 2006.

Appropriate values of most of the parameters were estimated iteratively until the model fit the F-22 price data. The a_0 and exogenous LC slope coefficient were determined primarily by the fit to the data. Other initial model parameters were set to values established in previous analyses. For example, the coefficient on capital (β) was based on a previous IDA study[21] relating the capital intensity of airframe manufacturers to unit manufacturing labor hours. Additionally, the 4 percent MYP discount (θ) was based on a RAND study.[22] The initial contract fee (π_0) was based on representative F-22 experience. The relatively high assumed discount rate reflects an elevated cost of capital associated with volatile future revenue streams due to uncertainties in future quantities. The final parameter estimates are listed in Table 4. The parameter names correspond to their definitions listed in Appendix A.

21 Bruce R. Harmon, "Cost Estimating Techniques for Tactical Aircraft Manufacturing Labor" (PI/LR), IDA Paper P-4490 (Alexandria, VA: Institute for Defense Analyses, 2012).

22 Obaid Younossi et al., "F-22A Multiyear Procurement Program: An Assessment of Cost Savings." MG664 (Santa Monica, CA: RAND Corporation, 2007).

Table 4. Final Parameter Estimates

Parameter	Setting
T_1 cost (a_0)	\$325 Million (FY10)
Exogenous learning curve *(b)*	82% *(b*= -.286)
Regulatory lag period (ℓ)	2 years
Facilities capital mark-up (γ)	17.5%
Annual discount factor (B)	0.85 which is a discount rate of 17.6%
Coefficient on capital (β)[a]	0.15
Capital stock residual value (φ)	50%
Depreciation rate (δ)	10% per year
MYP discount (θ)	4%
Initial capital intensity ($\frac{k_0}{C_0}$)	20%
Initial contract fee % of cost (π_0)	13%

Note: α was not specified directly, but was calculated from $\frac{k_0}{C_0}$, β and a_0.

Also of interest were values for secondary outputs. Least squares regression was used to fit a conventional LC model to the F-22 data.[23] This analysis produced an LC value of 78.4 percent. This bounds the steepness of the exogenous LC, as the 78.4 percent observed LC includes both exogenous and endogenous learning.

The parameters relating to capital (α, β, φ, and δ) were calibrated using model outputs for $\frac{\hat{k}_t}{\hat{C}_t+\hat{D}_t}$ where an analog value can be calculated from contract negotiation data reported on DoD Form 1547.[24] Two constraints on investment and capital were a minimum for $\frac{k_t}{C_t}$ of .20 and a maximum lot-to-lot increase in k_t of 75 percent. These assumptions smoothed lot-to-lot swings in model outputs and are not unrealistically restrictive on investment behavior.

Figure 5 presents the fit of the model outputs for unit price against actual unit prices taken from the budget data.

23 Because the final lot shows an increase in unit price associated with "tail up" costs, it was not included in the data used to fit the learning curve.

24 The value of equipment used on a contract has to be estimated in order to calculate the facilities capital markup (equipment employed) portion of profit; the equipment cost is considered analogous to $\hat{k}_t$. The carets above the variables indicate values estimated by the government at the time of contract negotiation.

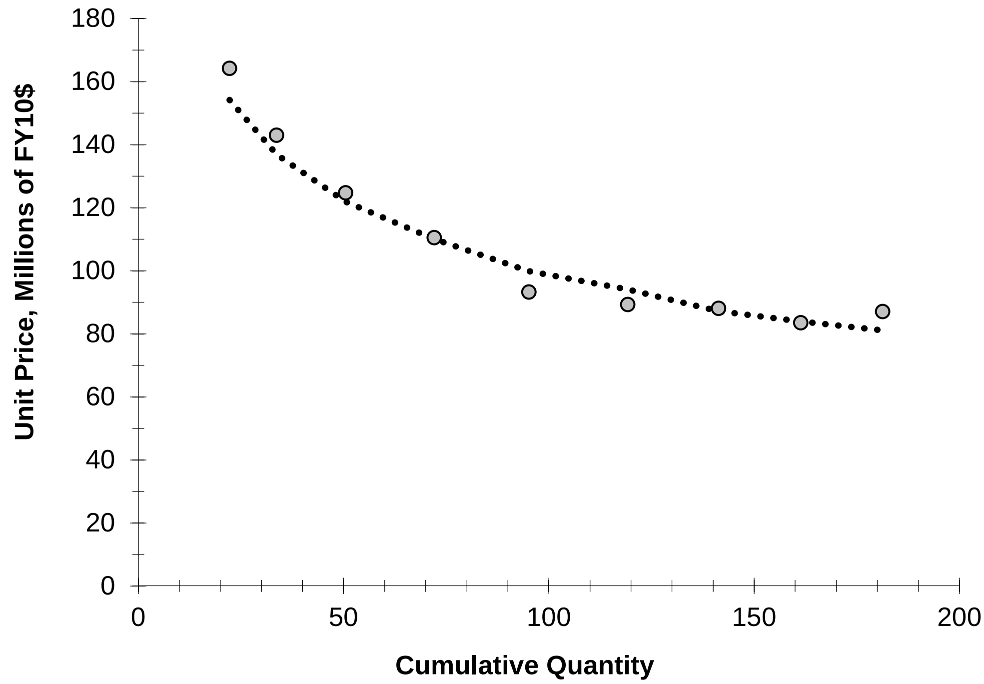

Figure 5. Model Estimates (Dotted Line) Compared with Actual F-22 Airframe Unit Prices

The calibration also yielded other interesting points. The weighted average capital intensity ($\frac{\hat{k}t}{\hat{C}t+\hat{D}_t}$) was estimated to be 22 percent, which is 10 percentage points higher than the weighted average calculated from the F-22 production contract negotiation data in the DoD Form 1547 database. This discrepancy is mostly resolved by accounting for the inconsistency between the capital cost and the recurring cost. The former is only for the prime contractor, whereas the recurring cost includes outsourced material. Given that the airframe is about half outsourced, the model estimate of the capital intensity is much closer to the ratio estimated from the Form 1547 database.

On average, each investment dollar resulted in around four dollars of cost savings over the entire program—this 4/1 payoff ratio is somewhat less than expected based on anecdotal evidence.

The estimate of the realized profit rate over all nine lots was 16.6 percent; dividing the nine lots into the eight SYP and one MYP contracts, the realized rates were estimated to be 14.7 percent and 22 percent, respectively. The estimated MYP profit premium of 7.3 percent (as measured as the difference between the excess estimated realized profit over the model-estimated negotiated fee for the MYP and SYP portions of the program) is higher than observed from actual F-22 contract data. By using the negotiated fee rates in the Form 1547 database and a proprietary dataset of observed realized profits, an empirical MYP profit premium for the F-22 was calculated at 4.2 percent.[25] One possible reason for this discrepancy is that the model did not take into account the government's ability to negotiate the lower costs associated with ex ante learning.

This suggests that the model overestimates the MYP profit premium. This does not yet provide insight into whether the MYP is or is not beneficial to the government. This will be revealed in the next section where the model with calibrated parameters is used to more explicitly test the effectiveness of the incentive investment.

2. Scenarios Analysis

The IIA model was used to estimate the relative effectiveness of the implied investment incentive in an MYP when compared to alternative procurement strategy scenarios. Four scenarios were examined, all using the same parameter values:

- **Baseline MYP**: baseline production schedule and quantities with SYP for the first six lots and MYP for the final three lots.
- ***Baseline SYP***: baseline production schedule and quantities with SYP for the final three lots vice MYP as in the base case.
- ***Extended 5 x 2 MYPs***: baseline production schedule through Lot 6 (FY 2006) followed by two five-year MYP contracts with a production rate of 36 per year.
- ***Extended 10 SYPs***: baseline production schedule through Lot 6 (FY 2006) followed by 10 SYP contracts with a production rate of 36 per year.

In addition to these four scenarios were two benchmark scenarios for the baseline and extended SYP cases. These scenarios are called *Baseline SYP Planner* and *Extended 10 SYPs Planner*. This was done assuming a social planner who can see the future and uses this knowledge to choose an investment plan to minimize the total cost of the program. The planner solves the following:

$$min_{\{i_t\}} \sum_{t=0}^{T} B^{\mathrm{t}}[C_t + i_t - \varphi k_T] \ .$$

The contractor's problem, in contrast, is to maximize its NPV from the production program.

3. Baseline Scenarios

Table 5 presents summary data for the scenarios for the baseline schedule.

[25] Details behind the calculations are included in Appendix A, although the observed F-22 data are omitted because they are proprietary.

Table 5. Model Outputs for Baseline Scenarios

Output Value	Baseline MYP	*Baseline SYP*	*Baseline SYP Planner*
Unit price total program (FY10$M)	103.5	103.3	101.3
Unit accounting cost, total program (FY10$M)	88.7	89.5	86.0
Realized profit, total program	16.6%	15.5%	17.8%
Unit price, last 3 lots (FY10$M)	84.1	84.2	82.8
Unit accounting cost, last 3 lots (FY10$M)	68.9	73.2	71.0
Realized profit, last 3 lots	22.0%	15.0%	16.6%
Total investment (FY10$M)	579	520	756
Contractor net present value (FY10$M)	1,320	1,273	1,251

The results were consistent with expectations that higher implied regulatory lag with an MYP will motivate the contractor to make more cost reduction investment in order to realize higher profits when compared to the SYP baseline. The social planner is the benchmark for what the government might desire the investment cost reduction profile to be. The contract price outcome is slightly worse than in the Part 1 findings. Putting the MYP at the end of the acquisition program locks in the Lot 7 prices. The MYP incentive works as expected, but without the opportunity to negotiate lower prices, the government forgoes the benefit. The contractor's NPV is substantially better under the MYP scenario. Also, the 4 percent MYP discount, smaller than the assumption in Part 1, only applies to a small number of aircraft. However, the IIA does not consider the cost of the AP and TL.

Figure 6 shows the capital intensity ratio over the course of the acquisition program for three scenarios. In the MYP case, the contractor has the incentive to hold off cost-reducing investments until just prior to the MYP—knowing that the cost savings are more valuable during the MYP as the contactor can retain all of the additional profits through the end of the program. This phenomenon is responsible for the higher price for the SYP contracts prior to the start of MYP. As the MYP price is negotiated using data from a previous SYP contract, the 4 percent MYP discount is partially offset by the higher cost basis vice the Baseline SYP case.

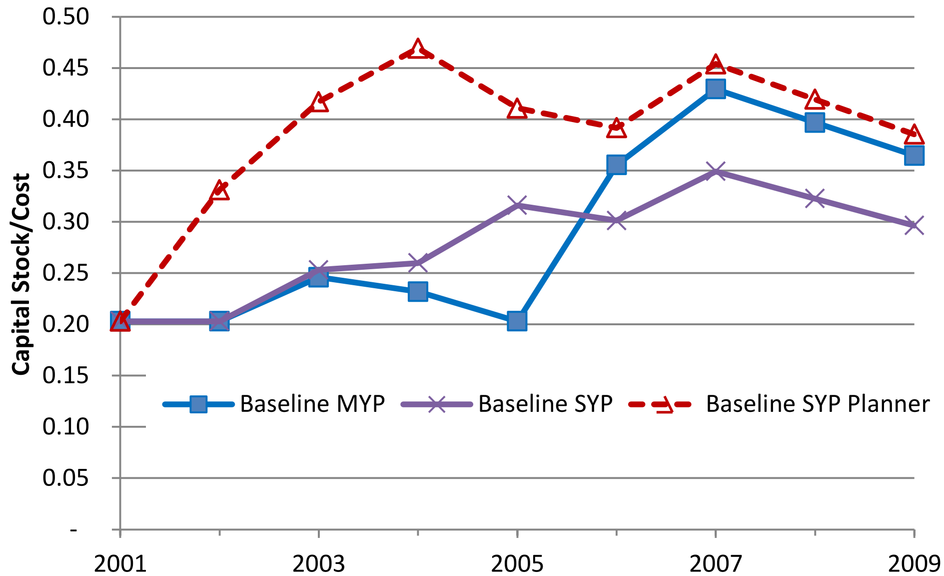

Figure 6. Model Outputs for Capital Intensity: Baseline Scenarios

4. Extended Scenarios

Table 6 presents summary data for the scenarios for the baseline schedule.

Table 6. Model Outputs for Extended Scenarios

Output Value	*Extended 2x5 MYPs*	*Extended 10 SYPs*	*Extended 10 SYPs Planner*
Unit price total program (FY10$M)	80.7	82.6	79.6
Unit accounting cost total program (FY10$M)	68.4	72.2	67.8
Realized profit, total program	17.9%	14.4%	17.4%
Unit price, last 10 lots (FY10$M)	70.3	72.7	69.7
Unit accounting cost, last 10 lots (FY10$M)	58.8	63.2	59.8
Realized profit, last 10 lots	19.5%	15.0%	16.6%
Total investment (FY10$M)	1,303	1,050	1,614
Contractor net present value (FY10$M)	2,010	1,820	1,729

Were the acquisition plan extended for the F-22, the model indicates that multiple MYP contracts would yield a more positive outcome for the government than it did in the base case. The price savings on the MYP lots are close to the 4 percent specified MYP discount. In the extended case, the government has the opportunity to capture the additional cost savings in the negotiation of the second MYP price. This is seen in the time series of unit prices presented in Figure 7.

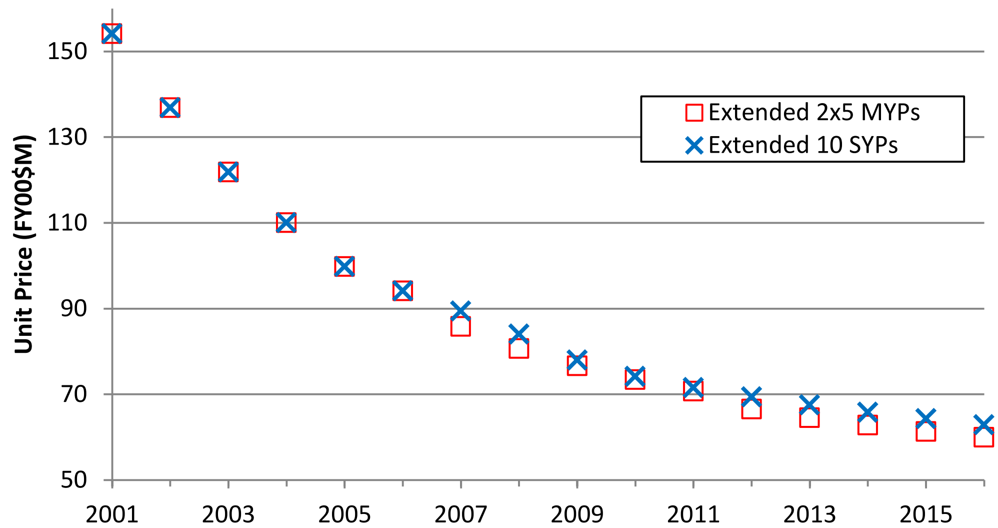

Figure 7. Unit Prices for Extended Scenarios

In the extended SYP case, the contractor also held back investment in the early lots, anticipating higher profits available with the increase in production rate to 36/year. This contrasts with the baseline cases, in which the last lots were bought at a lower production rate. This phenomenon can be seen in the time series of capital intensity in Figure 8.

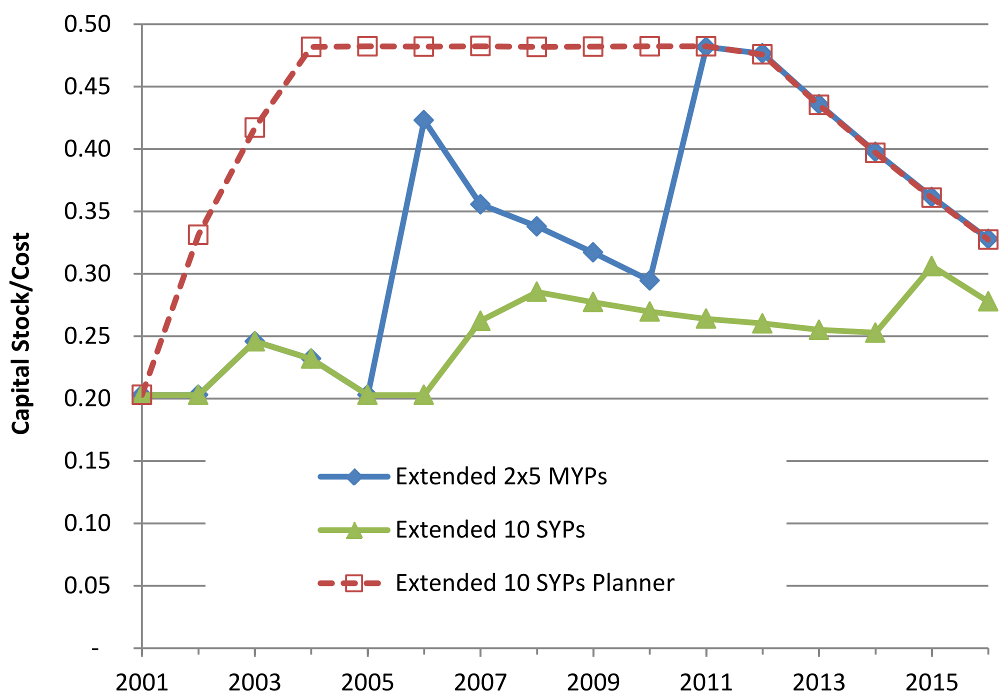

Figure 8. Model Outputs for Capital Intensity: Extended Scenarios

As in the baseline case, the contractor sees a meaningful increase in its NPV. In both MYP cases, the amount of investment is closer to that specified by the social planner.

5. Part 2 Conclusions: MYP Investment Incentive Analysis

The IIA shows that the added incentive effect from the longer regulatory lag in an MYP leads to more cost reduction investment by the contractor. This agrees with business intuition that greater revenue certainty would induce contractors to take greater risks to improve profits. The problem for contracting authorities is whether these reductions can be captured in lower contract prices. The IIA scenario analyses agree with the simple approach taken in the CBA, that without the opportunity to negotiate new prices, the savings will be retained by the contractor.

Clearly, residual cost reductions made in the last contract of a series are fully retained by the contractor. Only multiple MYP contracts give the government the opportunity to capture the additional cost savings that flow from contractor incentives. When an acquisition plan anticipates future MYP contracts, Figure 6 and Figure 8 raise the possibility that contractors may elect to postpone cost reductions until that point in the future. This is an unfortunate incentive misalignment that is difficult to fix. Moving the MYP earlier is only feasible if the program is sufficiently stable.

Given the strong investment incentive embedded in the MYP contract, the government should anticipate those additional cost savings as it is negotiating the price. This is by no means an easy task, given the government's inherent informational disadvantage in these types of negotiations. One area of research that could help this cause is to develop a tool that predicts the cost reduction propensity of a given MYP contract. This tool could be developed from examining historical contract costs.

F. Summary and Conclusion

Two modeling approaches have been used in this analysis to assess the cost and benefits of MYP contracts. MYP contracts are commonly known to offer a discount on the same quantity under a series of SYP contracts: the CBA and the IIA both use this assumption. But the cost of the erosion in appropriations and re-pricing flexibility have not been quantified in past business case analyses. This analysis has provided an estimate of these costs based on assumptions, but further empirical analyses are required to verify these results.

The first key findings in the CBA are that the AP and TL are significant costs that effectively erode the MYP discount. These costs are dependent on the interest rate and have been relatively low for the past decade. Should interest rates rise, the cost of the AP and TL requirement could more than offset the MYP discount.

The second key CBA finding is that by reducing the number of contracts that are negotiated, the MYP limits the government's options to capture and negotiate cost savings into new prices. This flexibility loss is more important earlier in the acquisition plan, when the rate of learning is greatest, but still applies to MYPs later in the plan. While this finding is intuitively obvious, the CBA model was used to show that the loss in flexibility can be quantified. If the government has sufficient insight into the potential for cost savings, it can estimate minimum MYP discount requirements, given the relative prospective LCs of the alternative procurement strategies. Generally, from Figure 3, if both the MYP and SYP strategies have the same anticipated ex post learning, the steeper the LC, the higher the minimum required MYP discount. If both strategies expect 80 percent learning, the minimum MYP discount is about 13 percent to justify the MYP contract. The minimum discount drops to 5 percent when learning is expected to be a 95 percent curve. Every 1-percentage-point drop in the expected MYP LC relative to that expected from the SYP strategy requires the MYP discount to rise by almost 5 percentage points.

The IIA model provides two key findings. The first is that the implied investment incentive in the MYP should induce contractors to increase their cost-reducing investments over what they would otherwise invest under an all-SYP strategy. The prospect of revenue certainty, through an increased regulatory lag, induces the contractor to take greater cost-reducing investment risks.

The second IIA finding is that the benefits of the investment incentive to the government depend on whether the savings can be negotiated ex post into subsequent contracts or ex ante into the first MYP contract. Multiple contracts, either MYP or SYP, are required in order to negotiate ex post cost savings into new prices. Ideally the government should try to anticipate ex post cost reductions and make these savings part of the MYP discount.

Both models agree that the net savings from MYP contracts can be eroded by the loss in either appropriations or re-pricing flexibility. The government should be wary about entering into a single MYP contract in a given program, particularly if there is no follow-on production. Contracting authorities need to be honest when assessing their effectiveness at price negotiation. Good price negotiators should not readily give up their option with an MYP contract to incorporate cost monitoring into annual re-pricing, whereas it is axiomatic that less effective price negotiators have no business locking up prices in a long-term contract.

Long-term contracts can be very effective incubators for contractor-led efficiency searches that ultimately lower procurement costs. Procurement strategies that use these types of contracts need to be carefully designed with the same or even greater understanding of the underlying production costs. This analysis corroborates the notion that greater incentive for contractors to seek cost reductions exists under an MYP. The question the program officials must honestly answer is how much of these savings will be captured. The IIA and earlier IDA work estimating the value to the contractor of reduced revenue volatility showed that an MYP contract provides value to the contractor that is not normally recognized during contract negotiation. The government contracting authority should try to regain some of this value in the form of lower negotiated costs or fee.

One predictor of a program official's prospects should be their experience with the preceding sequence of SYP contracts. If the program has not been successful in discovering recurring cost savings in the past, it is unlikely to gain much from an MYP. Capturing cost reductions should not be just through random luck, but embedded in the contracting processes and information systems.

Given the program official's ability to wring out procurement costs, the decision as to whether to use an MYP strategy rests on whether the NPV of the discount (i.e., the present value of the discount less the required incremental AP and TL costs) exceeds the value of the re-pricing option afforded through more frequent SYP negotiations. This decision can be analyzed quantitatively using the simple methods outlined in this report. Further research should be done to verify the methodology by examining historical contract cost data.

Appendix A.
Incentive Investment Analysis Model Specification

Contractor costs in constant dollars follow an exogenous LC, where, for the SYP contract:

$$C_t^{SYP} = q_t a_t Q_t^b,$$

where q_t, a_t, and Q_t are lot quantity, T_1 cost (when $a_{t=}$ a_o) and cumulative quantity (measured at the lot midpoint) for lot t; b is the exogenous learning parameter. For MYP contracts we added a step-down factor θ to account for MYP-unique cost savings:

$$C_t^{MYP} = \theta q_t a_t Q_t^b.$$

Costs can be associated with either contract type where $C_t = \{C_t^{SYP}, C_t^{MYP}\}$.

Cost reductions due to investment are reflected in a_t; its value is determined by the stock of capital (k_t), which in turn is determined by investment (i) in the previous period:

$$k_{t+1} = k_t(1-\delta) + i_t,$$

and δ is the depreciation rate per lot. One challenge in fully specifying the model was in representing the functional relationship between the level of k_t and a_t. The overall level of activity changes over the course of the production program, while a_t does not scale with that activity (while the costs associated with the activity do). Given this, we needed the relationship to be sensitive to the intensity of k_t as opposed to its level. Intensity is usually represented by the capital/labor ratio; however, the F-22 data did not support this metric. Instead we used lot cost (C_t) as a proxy variable for scale. The relationships between k_t and costs are expressed as:

$$a_t = \alpha \left(\frac{k_t}{C_t}\right)^{-\beta};$$

β is roughly equivalent to the parameter on capital in a Cobb-Douglass production function.[26]

While the specification of costs is parallel between MYP and SYP contracts, price determination is divergent. For both cases, the contract price (negotiated unit cost plus some fee percentage) is determined solely on the basis of information available to the government prior to the negotiation of the contract. The vintage of that information depends on the regulatory lag length (ℓ) in force. But for an MYP, many more periods pass before the government can renegotiate based on discovery of actual costs.

Investments made by the contractor within the regulatory lag period will tend to result in cost levels below those negotiated as part of price determination. Estimated costs used to negotiate the lot t price for each SYP contract are:

$$\hat{C}_t^{SYP} = q_t a_{t-\ell} Q_t^b,$$

where $a_{t-\ell}$ and $\hat{C}_t^{SYP}$ are based on information available prior to the lag period (t-ℓ); cost decreases due to investments are modeled as reductions from T_1 cost, where $a_t \leq a_{t-\ell}$ given positive net investment. To these costs, we added the depreciation expense (D_t), which is treated in negotiation as a cost that can be recaptured in price:

$$D_t = \delta k_t \text{ and } \hat{D}_t = \delta \hat{k}_t = \delta \hat{C}_t \left(\frac{k_{t-\ell}}{C_{t-\ell}}\right),$$

where the government assumes the lagged period's capital intensity when estimating depreciation. For an MYP contract, the cost for a given period used in negotiation would be:

$$\hat{C}_t^{MYP} = \theta q_t a_{m-\ell} Q_t^b,$$

where m indexes the first lot of the MYP contract. For the jth MYP contract covering n periods, the total cost used in negotiation would be:

$$\hat{C}_j^{MYP} = \theta \, , \sum_{t=m}^{n} q_t a_{m-\ell} Q_t^b.$$

Analogous relations were used for the depreciation expense.

The revenue for period t was specified as:

$$R_t = (1 + \pi_t)\left(\hat{C}_t + \hat{D}_t\right),$$

[26] Note that there appears to be a simultaneity problem as a_t both helps determine and is partially determined by C_t. However, given reasonable values of β, this relationship is convergent, allowing us to perform the optimization problem, albeit with additional manual steps.

where π_t is the fee rate on accounting costs. π_t consists of two elements:

$$\pi_t = \pi_t^k + \pi_t^c \ ,$$

where π_t^k portrays the facilities capital mark-up specified in the Federal Acquisition Regulation (FAR)-weighted guidelines,

$$\pi_t^k = \frac{\gamma \hat{k}_t}{\hat{C}_t + \hat{D}_t} \ ,$$

where γ is analogous to the FAR's facilities capital mark-up rate, which would normally be applied to net book value. π_t^c reflects the remainder of the mark-up on accounting cost.

The contractor's objective for a given program is:

$$max_{\{i_t\}} \sum_{t=0}^{T} B^t [R_t - C_t - i_t + \varphi k_T] \ ,$$

where B is the discount factor, i_t is investment for lot t, k_T is the capital stock at the end of the program, and φ is the proportion of k_T that has value after the conclusion of the program. The decision variable is i_t. Implied assumptions are that the contractor has perfect foresight regarding lot quantities and all parameters are non-stochastic. This problem can be solved using the nonlinear optimization functionality in Microsoft Excel.

One empirical implication of the model solution is the MYP profit premium referred to in the text. We compared the differences in negotiated and realized mark-ups between the SYP and MYP contracts for both the model-generated and observed data for the Baseline MYP case. For the model-generated data:

$$MYP\ profit\ premium = \Delta = \left(\frac{\sum_{t=m}^{T} R_t}{\sum_{t=m}^{T} C_t^{MYP}} - \frac{\sum_{t=m}^{T} R_t}{\hat{C}_j^{MYP}}\right) - \left(\frac{\sum_{t=0}^{m-1} R_t}{\sum_{t=0}^{m-1} C_t^{SYP}} - \frac{\sum_{t=m}^{T} R_t}{\sum_{t=0}^{m-1} \hat{C}_t^{SYP}}\right),$$

where Δ = (22.0% - 13.0%) - (14.7% - 13.2%) = 7.5%. We observed analogous values for all of these variables in the DoD Form 1547 and contractor cost data. As the observed cost components were proprietary, we only reported the final value of 4.2 percent.

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14. ABSTRACT
Multi-year procurement (MYP) allows the Department of Defense to enter into up to a five-year contract to procure items that would otherwise be purchased through annual lot buys. By reducing the government's flexibility to change the quantities it buys each year, the contractor must commit to a significant price reduction over annual purchases of the same quantity. Further cost reduction incentives should result from extending the contractor's investment recovery horizon. This paper analyzes the cost and benefits of using procurement strategies that employ MYP contracts. The incremental cost of the MYP is the loss of budget flexibility, which the analysis attempts to quantify. The analysis also examines the potential power of the MYP cost reduction investment incentives. The analysis suggests that the stated savings associated with an MYP are significantly reduced by the cost of the lost budget flexibility. In addition, the loss in the opportunity to annually re-price contracts reduces the effect of the MYP discount. Annual re-pricing of contracts is an important process for reducing informational asymmetries that exist in sole source contracting.

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