Hyperbolic Discounting & Defense Acquisitions

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International Cost Estimating and Analysis Association (ICEAA) conference
9-12 June 2015

When officials at the Department of Defense (DOD) wish to add new capabilities to the warfighters' arsenal, they rely on outsourcing system technology development and production to private firms. This relationship between government and industry is almost exclusively intermediated through contract vehicles. The DOD transacted over 1.1 million new or modified contracts in fiscal year 2014 alone, the total obligation value of which exceeded $230 billion.[1] The primary concern here is not the scale of defense contracting, but its efficiency. A 2008 RAND study of 35 selected Major Defense Acquisition Programs (MDAPs) found these systems to have incurred 60% cost growth on average.[2] The Government Accountability Office (GAO) wrote that the new Zumwalt Class Destroyer experienced research and development cost growth of 341% and unit cost growth of 540% before the lead-ship was even delivered.[3] This essay will explore how hyperbolic discounting of the future, a time-inconsistent model of personal valuations, has significant effects on the defense contracting environment and leads to poor outcomes in two ways: 1) by allowing government officials to be more susceptible to modifications; and 2) by making private firm managers less responsive to current contract incentive structures. The analysis will help explain how cost growth has become endogenous to defense contracts and offer some solutions based on commitment schemes.

The principle of discounting is often applied as a financial mechanism to control for the "time value of money." An individual finds a certain quantity of money in the future less valuable than the same quantity today, even adjusting for inflation, because the availability of low-risk investment opportunities assures positive monetary returns. Discounting is often modelled exponentially as it tracks the expected growth path of financial investments. From observations of human behavior (e.g. Stroz 1956; Ainslie 1992; Laibson 1997; Shapiro 2005) the exponential model of discounting may be less applicable to an individual's utility, as opposed to monetary, valuations. Their research suggests the use of hyperbolic discount functions which exhibits relatively high discount rates over the short-run and

[1] OMB.
[2] RAND, 37.
[3] GAO, 55-56. Total acquisition cost growth on the program has fallen 40% as the number of ships expected to be procured has dropped from 32 to 3. Additionally, "Three of the program's 11 critical technologies are mature; the remaining 8 technologies will not be demonstrated in a realistic environment until after ship installation."

relatively low discount rates over the long-run. In other words, with hyperbolic discounting people perceive present costs and benefits more intensely while the future is considered both less acutely and more homogenously.

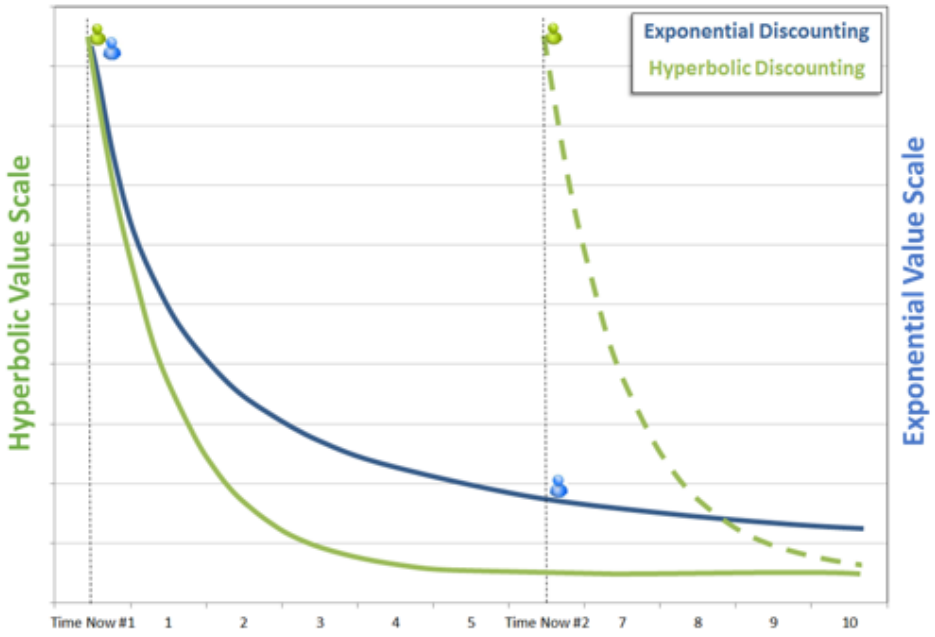


Figure 1: Exponential vs. Hyperbolic Discounting

Hyperbolic discounting has an intuitive effect on human preferences, making them dynamically inconsistent. After an individual develops a plan for the future to maximize utility, the key insight is that he may reconsider that plan at a later date. For example, gym memberships often only pay off if the person frequents the gym, but DellaVigna and Malmendier find that a majority of consumers who buy a membership do not visit enough for it to be a cost effective option.[4] These consumers would have realized substantial savings from per-visit passes. The authors conclude that agents overestimate attendance and future self-control. Everyday life is ripe with other examples of time inconsistency, from students procrastinating on homework to workers not saving as much of their income as they would like. Humans resolve this continuous repudiation of past plans through pre-commitment strategies such as creating penalties for failure or factoring in one's likelihood to disobey when developing plans.[5]

These findings imply that there is no unitary decision-maker in people's practice of hyperbolic discounting.[6] In other words, individuals inter-temporally battle with themselves in creating and sticking to plans. This schism is very real when applied to government contracting. Contract plans, developed by

[4] DellaVigna and Malamendier (2006), 716.
[5] Stroz, 173.
[6] Tabarrok.

one set of individuals, are executed by others who have the authority to renegotiate and modify. Defense contracts often have durations over many years, and development contracts can last in excess of a decade. Significant churn in management is the norm and top decision-makers often retire before contract delivery, leaving no one personally accountable. Bureaucrats have therefore endeavored to create their own commitment schemes to reduce the probability of contract modifications (referred to as "mods" from here forward). This takes the form of rigorous planning and requirements documentation, where all conceivable aspects of the desired system are laid out. Contractor performance is then measured to this plan and any complications can be attributed to them alone as opposed to new direction, or "scope," from the government side.

The planning effort that goes into defining all aspects of contract requirements is large by any standard. For example, one typical contract Statement of Work (SOW) included the word "shall" 258 times and referenced 68 other documents as applicable requirements to the SOW.[7] Many contracts require an Integrated Baseline Review (IBR) six months after contract award.[8] The IBR is a joint assessment by government and contractor personnel on the work scope, risks, and management control processes. Experience has shown, however, that even extensive requirements documentation cannot offset the need for contract mods. This is because many unknowns plague major defense acquisitions which tend to be large in scale, highly specialized, and integrate frontier technologies. Figure 2 below shows the average number and total value of fixed-price contract mods binned by contract award price.[9] For instance, fixed-price contracts with award value between $256-512M experienced an average of 78 mods worth over $890M. Because of such "rubber baseline" cases, where mods are continually negotiated, the government has come to rely on cost-plus contracts in which the firm is reimbursed on all costs incurred. Cost-plus contracts place the risk of cost growth on the government, but may also be viewed as an institutionalized form of fixed-price contracts with auto-modifications to avoid transaction costs. Over the past decade, 69% of Northrop Grumman's revenues from the U.S. Government came in the form of these cost-plus contracts while all other sources were 89% fixed-price.[10]

Cost-plus contracting, however, does not solve the time-inconsistency problem of redirecting contracts; it merely displaces risk and minimizes transaction costs. Government agents continually want to be plugged-into the decision making process, though detailed requirements were intended to relieve them of the need to do so. In Ronald Coase's 1937 "Nature of the Firm," he argues that when direction

[7] The proprietary nature of these contracts data prohibits the dissemination of further details.
[8] DAU, IBR.
[9] Cost-plus modifications not shown.
[10] SEC, Northrop Grumman Corporation 10-K Item 1 (2004-2013).

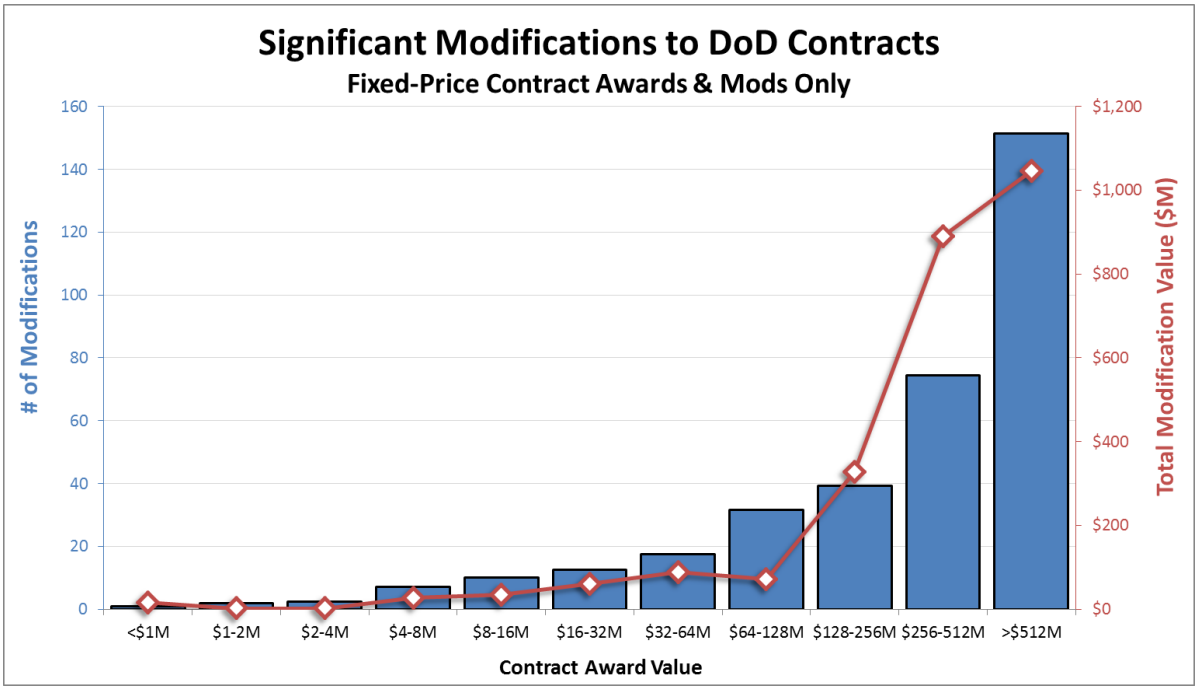


Figure 2: Fixed-price modifications for DOD contracts

***Source**: Air Force Cost Analysis Agency (AFCAA) Contracts Database (Publically Available). Includes 4,073 fixed-price contracts from across the military services dating back to Aug. 1991. Accessed November 11, 2014.*

of resources in a contract must be decided later by the purchaser, relative efficiencies can be gained by internalizing those resources to avoid transaction costs.[11] He writes, "owing to the difficulty of forecasting, the longer the period of the contract is for the supply of the commodity or service, the less possible, and indeed, the less desirable it is for the person purchasing to specify what the other contracting party is expected to do [….] A firm is likely therefore to emerge in those cases where a very short term contract would be unsatisfactory."[12] Given that in-house government production has become politically unpalatable, decision rights within the contract may be best left with the contractor itself. Jensen and Meckling argue that economic organization must solve two problems: "the rights assignment problem (determining who should exercise a decision right), and the control or agency problem (how to ensure that self-interested decision agents exercise their rights in a way that contributes to the organizational objective)."[13] "Collocation" of knowledge and decision-making is relatively efficient and can generally be serviced through markets, which tend to move decision rights to those with the production knowledge, or firms, which bring knowledge in-house to exercise decision-making. The government's attempt to bridge this divide has produced a curious mix. In order to be in a position to

[11] Coase, pg 390.
[12] Coase, pg 391.
[13] Jensen and Meckling, pg. 253.

make informed decisions on immature system contracts, the government imposes detailed cost and schedule reporting requirements through Earned Value Management (EVM) for those over $20M.[14] EVM dictates not only monthly reporting standards, but the management style more generally to conform to industry best practices. One might conclude that the bureaucrats attempt to duplicate entrepreneurial knowledge in order to continually assess its direction. As F.A. Hayek writes about such proposals: "All this involves planning on the part of the central authority on much the same scale as if it were actually running the enterprise [….] This division in the disposition over the resources would then simply have the effect that neither the entrepreneur nor the central authority would be really in a position to plan and that it would be impossible to assess the responsibility for mistakes."[15] Indeed, RAND found that decision-making represented 69% of their MDAP sample's average cost growth,[16] though it is not clear whether the bureaucrat has made new requirements or the contractor has discovered unanticipated hurdles.

The government's commitment scheme of detailed requirements may actually increase the likelihood of future mods. For example, a contractor which encounters engineering difficulties may be forced to make marginal tradeoffs in design; given that almost every aspect has been detailed in the contractual agreement, the ability to meet one requirement may come at the expense of another. On fixed-price contracts, this issue would supposedly be the contractor's alone to resolve and the firm would expect to take a loss or default. On cost-plus contracts, the firm will simply allocate more resources and the government's costs would grow in tandem. But in most cases government officials will write a mod that changes requirements which, in the case of a fixed-price contract, also likely increases the funding level. Because of the inherent uncertainty surrounding contract execution, the myriad of requirements leaves the firm without an option-space for building the best overall product at the prescribed price. Many performance parameters exhibit decreasing returns to cost; a marginal decrease in, say, empty weight to meet the requirement may necessitate a redesign of several other aspects. The Comanche helicopter, for instance, needed redesign to reduce weight by only 200 pounds (2.1%).[17] This and various other issues led to the program's termination in 2004.[18]

Not all scope growth is of this kind. In fact, a majority may occur because contracts have significant ceilings which are convenient vehicles to dole out marginal task orders. A common practice is

[14] IPMR, 8.
[15] Hayek, 237.
[16] RAND, 37.
[17] Jackson, 2007.
[18] Brownlee, 2004.

to price contracts aggressively and budget conservatively. Government agents, however, are weary of not obligating their full budgets for fear of seeing reduced funding in the future. It is difficult to say how much re-contracting is due to leftover budgets, especially since EVM reports are only required through 90% complete. Figure 3 below shows some available instances where contract performance on MDAPs reached 95% complete and subsequently received significant additional funding. Much of this cost growth is likely new scope added to the contract as opposed to the contractor suddenly realizing major issues in the twelfth hour. The circumstance becomes one where deliverables which are "nice to have" but not mission critical get worked into existing contracts, though from the perspective of the DOD at large there are higher valued uses for those dollars.

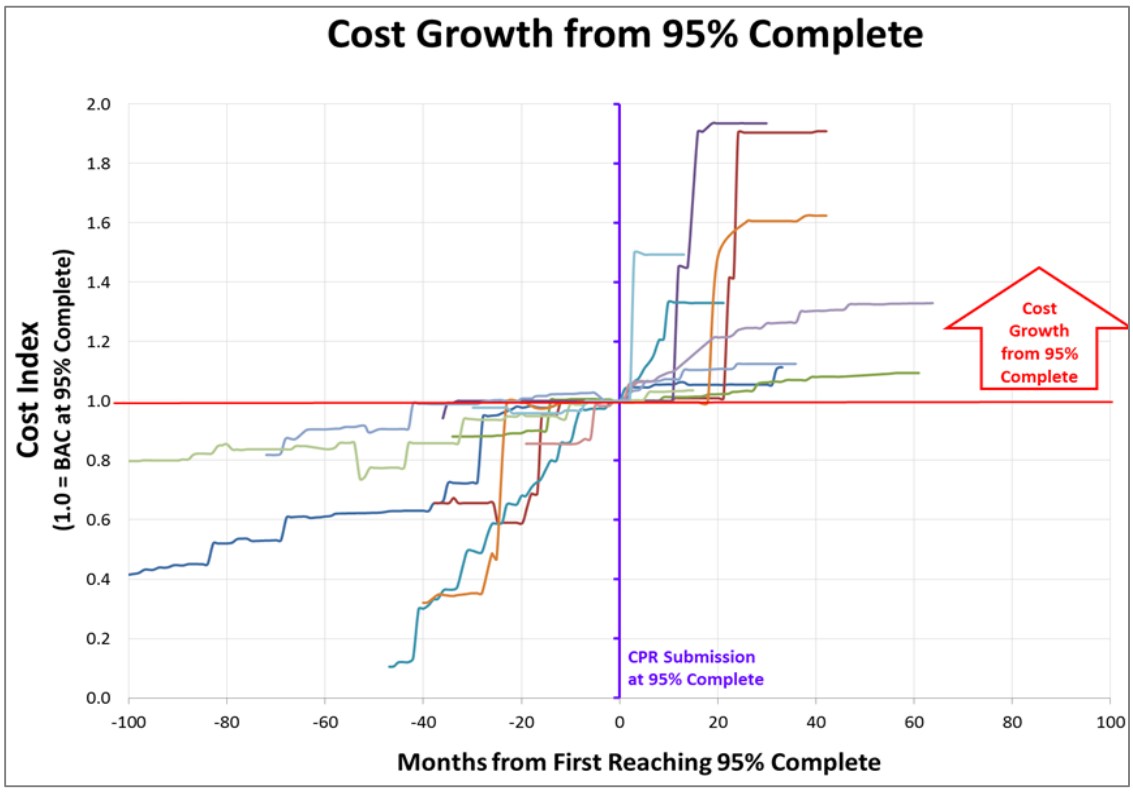


Figure 3: Sample of Contract Cost Growth from Reaching 95% Complete

***Source**: Earned Value Management Central Repository (EVM-CR). Sample includes 11 MDAP Contract Performance Reports (CPRs). BAC stands for Budget at Complete. See http://dau.mil for additional information.*

The prevalence of government scope changes throughout contracts can have a large theoretical effect on how firms bid on DOD contracts. These contracts are allocated to private firms through a procurement, or reverse, auction whereby the technically acceptable firm bidding the least price wins the contract. Each firm doesn't know what the actual cost of the job will be as uncertainties arising from quantifying factors and methods of production will affect all bidders. But each firm realizes that the other bidders possess signal information that it would find useful for its own cost estimate, allowing us to use the common values assumption of auctions as opposed to private values.[19] This illustration of auction theory requires us to assume that all firms are equally capable of performing the job at a cost *C,* and for simplicity we may suppose that bidders make unbiased estimates $X_i = C + \varepsilon_i$, where the errors are normally, identically, and independently distributed.[20] The result is that although each bid is unbiased, the lowest bid which ultimately wins the auction is biased downward and the winning firm's expected value is negative (i.e. is expected to make a loss on the contract). This occurrence, referred to as the "Winner's Curse,"[21] is represented in Figure 4 Below.

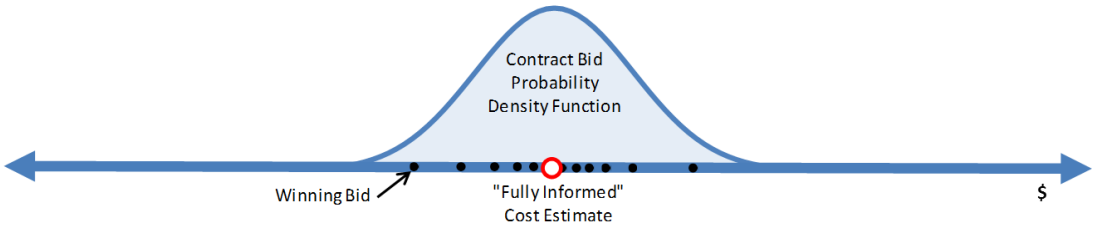


Figure 4: The Winner's Curse

Now let us assume that each participating firm recognizes time-inconsistency on the part of the government and anticipates contract modifications which will alleviate the expected loss associated with the "Winner's Curse." This may be because of government agents' continual redirection of contract requirements discussed above, or the too big to fail problem where firms believe that the importance of the project or company itself will require a bail out of poor performance. Either way, when numerous contract mods of relatively high value may be used to cover losses on the baseline contract, the firm's initial speculation is not disciplined by endogenous profit/loss feedback. What was expected to be a loss may in fact be a net profit after several rounds of re-contracting. Since there is no competition for contract mods, the mods may be overvalued to where they can cover not only new scope costs, but some baseline scope costs as well. For cost-plus contracts, mods are not needed to the same extent for

[19] Milgrom, 5.
[20] Milgrom, 5.
[21] Thaler, 192.

the underbidding firm to recoup costs. Their revenues automatically grow along with their costs, but mods are an important way to renegotiate profit rates eroded due to poor performance. Because losses or poor profitability can reasonably be expected to be negated in these ways, firms are likely to bias their initial bids downward in order to simply win the contract. I will call this phenomenon the "Winner's Blessing" problem and the result is that all bids are biased downward by an assumed identical term λ, represented in Figure 5 below. Depending on one's view of firm risk preferences, the downward bias may be interpreted in a couple of ways. Relatively risk loving firms see λ as the amount that the sum of future mods are expected to be biased upwards in order to cover baseline contract losses. Relatively risk averse firms see λ as an acceptable loss in return for expected profitability on future mods as well as follow-on work such as production or sustainment contracts.

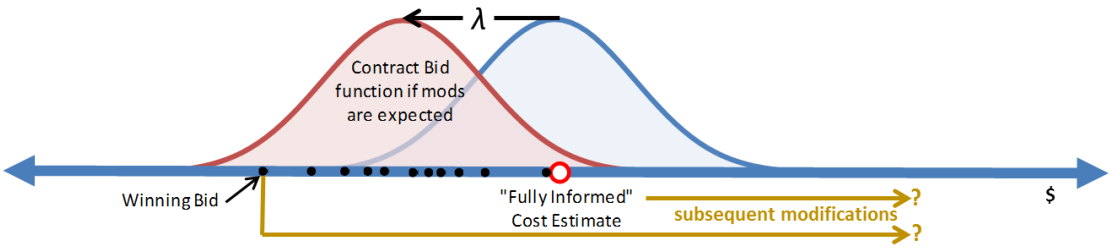


Figure 5: The Winner's Blessing

Support for this below cost pricing for consumers with time-inconsistent preferences has been demonstrated by DellaVigna and Malmendier (2004). They find that profit-maximizing firms price investment goods (those with immediate costs and delayed benefits) below marginal cost for consumers who are overconfident about future self-control.[22] In such markets, firms will back-load fees and transaction costs. They cite evidence for switching costs in industries such as credit cards, health clubs, mail order, newspapers, and life insurance.[23] Defense contractors don't utilize the same profit-maximizing tactics as in the consumer industry, but government analysts don't often scrutinize mod prices as they do for new buys or at milestones with independent estimates. Overpriced new scope translates to high profitability on that work – or the ability to cover overruns on baseline scope. Defense contractors also may expect to recoup costs through follow-on work. For example, Boeing bid aggressively on a fixed-price development contract for the KC-46A air-refueling tanker which the Air Force currently projects to be $1B over budget, but with an expected 179 production units worth about

[22] DellaVigna and Malmendier (2004), 363.
[23] DellaVigna and Malmendier (2004), 390-93.

$52B, Boeing is assured a significant business base.[24] The ability for contractors to largely remain shielded from uncertainty is shown in Figure 6 below, where the five major defense primes' average profit volatility over the past four years is exceedingly low relative to other sectors of the economy. Stock markets have priced these firms favorably; an index of those firms has climbed 119% in two years to Nov. 2014[25] despite the war in Afghanistan winding down and the budget sequestration leading to a 35% decline in defense contracts.[26] This provides some reasonable evidence that defense firms and investors at large expect substantial profitability despite a history of poor contract performance.

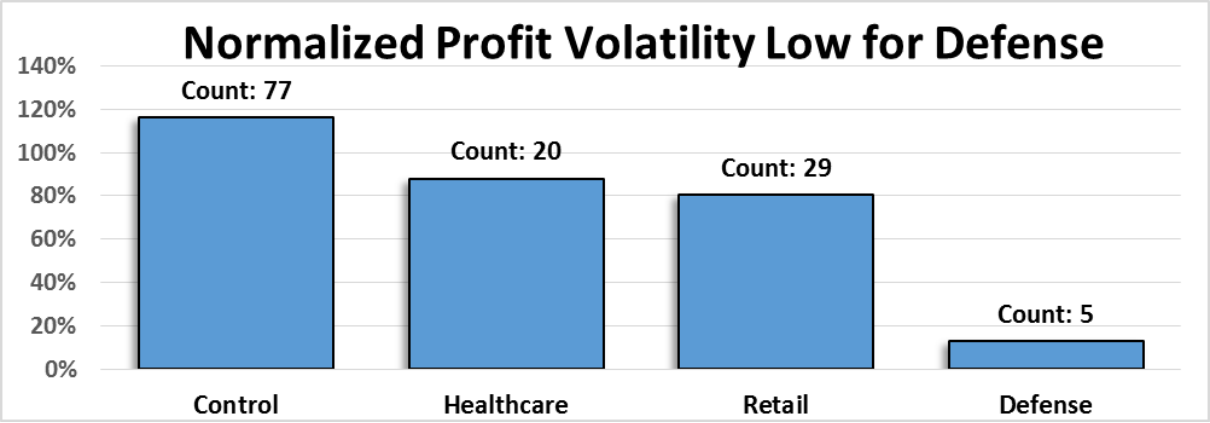


Figure 6: Standard Deviation Divided by Mean of Gross Profits as % of Total Revenues Within Sectors
***Source**: Google finance accessed through 'R' quantmod package. 20 healthcare companies from the NYQ list under Yahoo Biotechnology, Drug Manufactures – Major, and Hospitals. 29 retail companies in NYQ list under Yahoo category names Restaurants, Grocery Stores, and Department Stores. Defense firms include Lockheed Martin, General Dynamics, Boeing, Northrop Grumman, and Raytheon. Second tier defense firms not used because they tend to receive a majority of their revenue from defense primes as opposed to the government itself. Control group of 77 companies from a simple random sample of other company names. Gross Profits as percent of Total Revenues over four years (2010-2013) used to determine mean and standard deviation for each sector, the latter being divided by the former to derive the metric used in the chart.*

The simplest way for government agents to commit themselves to a set of requirements is to take contract mod power out of the government program manager's hands and place it in the hands of an independent agency. The program manager would have to inform the agency why the mod would be necessary, explain how the price was set, and why it is unrelated to mere poor contractor performance. This would not only take mod powers away from those who are "too close" to the contract and reduce mod occurrences, but force contractors to scrutinize performance requirements more closely before agreeing to take on a project. Such an independent body could be administered by the Defense Contract Management Agency (DCMA) which currently serves as "information brokers" that provides contract

[24] Reuters. Dated Nov. 19, 2014.
[25] Yahoo! Finance. See Appendix Figure 1.
[26] OMB. See Appendix Figure 2.

solicitation advice and monitors contract compliance.[27] In this role, the DCMA could also feasibly keep a centralized record of government management performance ensuring accountability and promoting visibility into root causes of supposed contract mismanagement.

Another commitment scheme would be to reduce the need to make mods in the first place. It has been argued above that the current government requirements documentation may exacerbate the need for contract mods in the future. This is especially true for research and development type efforts. A viable alternative may utilize similar characteristics to the pay on performance (PoP) bonds where firm profitability is based on measureable attributes. As opposed to writing performance objectives which the contractor must meet across the board for a flat profit rate, government agents can design a set of performance spectrums which pay out according to an incentive scale. For example, a new fighter jet contract can be auctioned in a first-price sealed bid form on contract target costs only. Though the winning bid is likely under the "true" cost, profits can be relatively large and tethered to performance scales. These performance measures (e.g. thrust-to-weight ratio) can be given acceptable ranges, the bottom being the requirement threshold, and profit payout increases as the performance measure improves. The incentive weights given to each performance measure signals to the contractor which attributes are particularly important to the mission needs. In this way the contractor can make tradeoffs themselves based on predefined parameters (e.g. reduce thrust-to-weight ratio to increase armor). It also allows the government to discontinue its requirements for EVM implementation as it moves decision rights to the contractor whose profitability is purely based on *ex post* measurements of system parameters according to predefined scales.

Similar schemes have been used in privatized prisons in which higher interest is paid for less offender recidivism.[28] This allows the contractor to discover the best overall good or service for the prescribed cost by freely making management tradeoffs without necessitating modifications. Defense contracts currently use some performance incentives,[29] but the contractor may earn these higher performance profits at the expense of higher overall costs due to forthcoming mods or cost-plus contract types. The PoP scheme may find its limit if the system also has many unmeasurable attributes which the contractor can substitute across. Incentivized measurable attributes can come at the expense of important unmeasurable ones. Some evidence for this exists; when doctors and hospitals are paid for good health outcomes they develop a selection bias leaving the sickest without access to care.[30] The PoP

[27] DCMA.
[28] Chen
[29] FAR 16.402-2
[30] Dranove, Kessler, McClellan, and Satterthwaite, 572.

scheme may prove beneficial when there are few unmeasurable attributes or when they are complementary to measureable ones.

Other work which the PoP type scheme would not provide significant gains is in relatively mature production contracts. When system attributes are proven and stable, performance parameters do not need to be incentivized so much as overall cost reductions through efficiency gains. These contracts today tend to use the fixed-price plus incentive fee contracts where cost savings are split between the contractor and the government.[31] At the outset, target cost and profit are negotiated along with a "share ratio." Upon contract completion, actual costs are compared to the target costs with the differential being the basis for the realization of profits. For example, a 25:75 share ratio means that for every dollar the contractor completes the order less than the target cost and within the range of incentive effectiveness, 25 cents is returned to the government and the contractor receives 75 cents in addition to the target profit (see Figure 7 below). Because the contractor must submit detailed cost reports and have their accounts audited by the Defense Contractor Audit Agency (DCAA), in theory contractors are not able to covertly reduce costs and keep excess savings as profit.

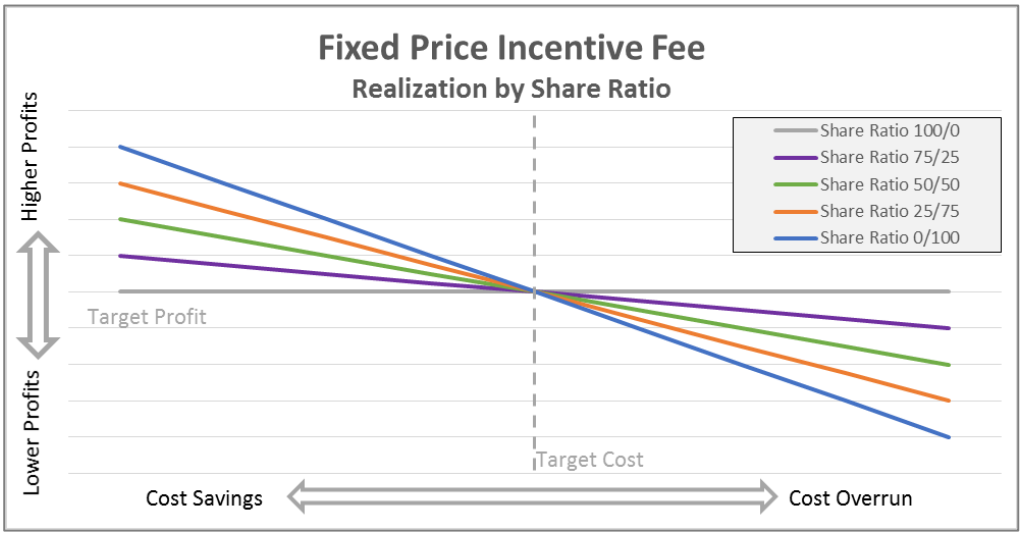


Figure 7: Fixed-price Incentive Fee by Share Ratio

Note that within range of incentive effectiveness, a share ratio of 0/100 is equivalent to a firm-fixed-price contract where the contractor realizes the 100% of underruns as profit and 100% of overruns as reduced profit/losses. Conversely, a share ratio of 100/0 is equivalent to a cost-plus plus fixed fee contract in that the government retains 100% of any cost underrun but foots the bill for 100% of all overruns.

[31] FAR 16.402-1

This contract incentive structure appears to work well by incentivizing cost reductions and bringing some share of the savings back to the government. Because of product stability, the issue here is not so much a prevalence of mods but asymmetric information as only the contractor knows their real costs. If they do experience substantial efficiencies but report costs as being on target, then they can keep the entirety of the savings and share none with the government. These contracts would therefore continue to require beginning and end of contract submissions of Cost and Software Data Reports (CSDRs)[32] on the part of the contractor and auditing by the government. They would not, however, require the implementation of EVM, allowing the contractor to utilize or innovate management techniques that can increase efficiency.

Recognizing that contractor management may also be afflicted by the time-inconsistency problem, there is room for improvement on fixed-price plus incentive fee contracts. Because the current incentive structure is smooth and continuous, each incremental realization of cost growth only hurts profits by a small amount. Control Account Managers (CAMs) from the contractor with hyperbolic discounting might then be lax on their cost management in the short term and overestimate their abilities to make up ground in the future. When reporting expectations for cost and schedule growth, such over-optimism about the future leads CAMs to be downwardly biased. Using actual Integrated Master Schedule (IMS) data from 12 MDAP contracts, some evidence for this claim will be provided.

Figure 8 below depicts the trend of one of the most utilized schedule metrics, the Baseline Execution Index (BEI). The BEI indicates the efficiency with which tasks have been accomplished when measured against the baseline.[33] BEI values of 1.0 represent completing the same number of tasks as had been planned by the submission's 'as of' date. Values above 1.0 represent working ahead of plan and value below 1.0 represent falling behind in task completion. One can see from Figure 8 that despite actual performance (blue) falling, the forecast task performance (red) climbs to implausibly high levels. Though 8 of these contracts were cost-plus, this clearly demonstrates that CAMs within the sample overestimate their ability to execute in the future, and in general that bias increases as the project progresses.

[32] Defense Cost and Resource Center (DCARC).
[33] DCMA, "Earned Value Management System (EVM) Program Analysis Pamphlet (PAP)," pp. 16-18.

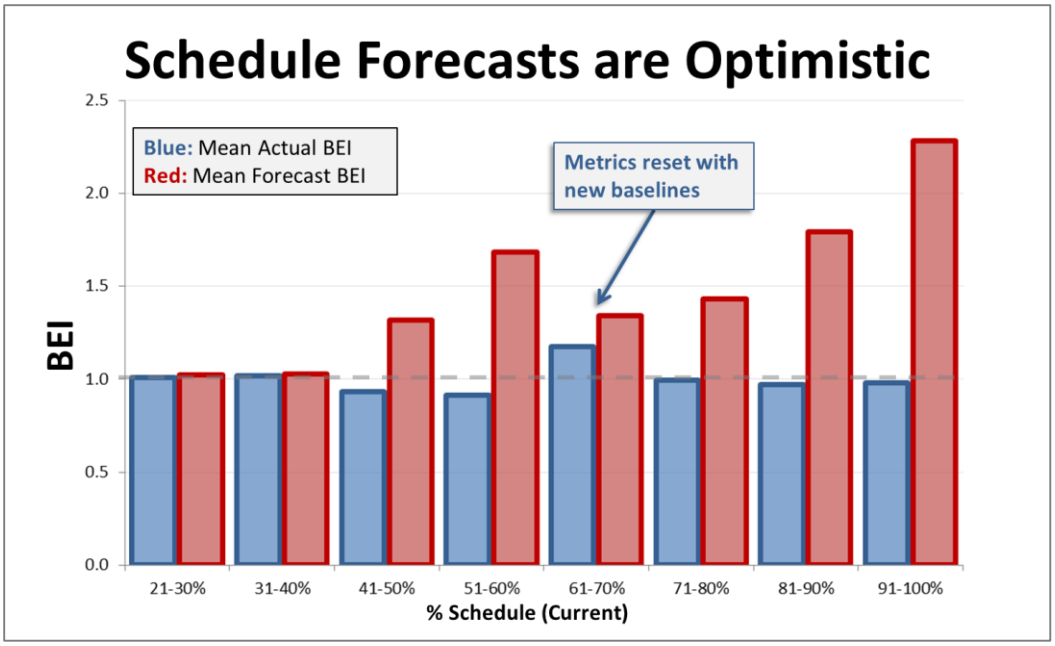


Figure 8: Schedule Performance Forecasts Optimistic Relative to Actuals

***Source**: Earned Value Management Central Repository (EVM-CR). Sample includes 12 contracts and 133 observations. Only contracts in MS Project were utilized for which reports were submitted from contract start to finish. Contracts often see new baselines around 60-70% complete where performance is reset – the effects of which are seen above. See Lofgren, 2014.*

The result of CAMs optimism is that the IMS does not alert management to likely schedule slips until relatively late. From the same data sample as Figure 8, Figure 9 below shows that little to no schedule growth was reported until well after 50% of the negotiated contract duration; thereafter significant growth was incrementally realized. In fact, as a project approaches its expected end date further delays are developed, creating a tail chase.[34] This situation exhibits the constant repudiation of past plans. The IMS itself is not a commitment scheme, but rather an embodiment of prevailing beliefs. If CAMs acknowledged their tendency to discount hyperbolically, we would expect forecast performance to reflect actual performance and schedule slips to be reported earlier. Since they do not, the remaining commitment scheme of penalizing underperformance does not currently appear to provide strong enough incentives. These considerations can only be addressed by contractor management and can help to increases the reliability of the reporting but not necessarily the effectiveness of work execution.

[34] Druker, et al.

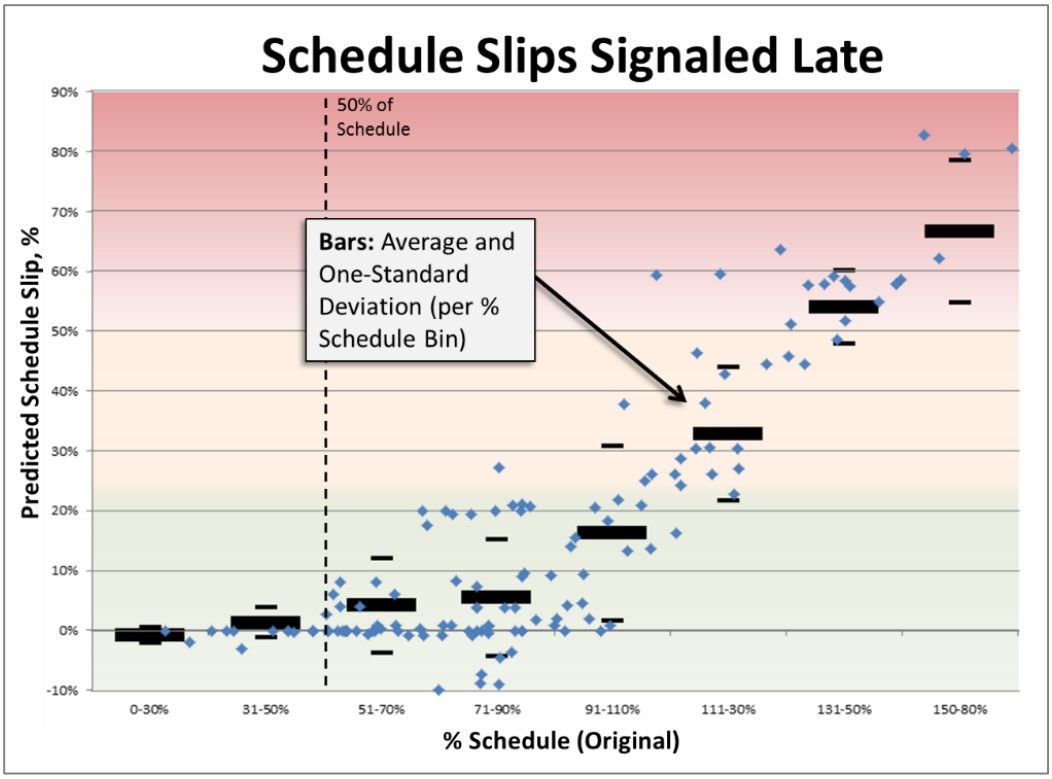


Figure 9: Schedule Slips not Admitted to Until Late in the Contract

***Source**: Earned Value Management Central Repository (EVM-CR). Sample includes 12 contracts and 133 observations. Only contracts in MS Project were utilized for which reports were submitted from contract start to finish. See Lofgren, 2014.*

A potential way to for the government to help commit contractors to exerting more effort in the short term is to utilize discontinuous incentive structures. An example of this is provided by Kaur, Kremer, and Mullainathan where they found that workers in India often chose a nonlinear piece rate contract which penalized the workers for not achieving a threshold.[35] The nonlinear contract was at all points lower than the linear one up until the threshold output value, whereby it had a discontinuous jump and matched the linear contract there forward. The authors find that for production with long time horizons, lags between work output and subsequent revenues generate suboptimal effort in the early stages.[36] The choice of the nonlinear piece rate contract could then be viewed as a commitment mechanism that workers self-selected to induce higher output and avoid over-working closer to payday deadlines. The authors found that workers who chose the commitment contract with a high target increased productivity by 6% of mean production.[37] Though CAMs are not paid piece rates, their performance is continually assessed based on their ability to meet cost and schedule targets. As

[35] Kaur, Kremer, and Mullainathan (2013), 20.
[36] Kaur, Kremer, and Mullainathan (2010), 626.
[37] Kaur, Kremer, and Mullainathan (2013), 27. Estimates significant at the 5% level.

pressure becomes more acute late in the contract the CAMs often don't perform to early expectations given that they discount the future hyperbolically. Instead of linear incentive structures as depicted in Figure 7, the DOD could utilize a nonlinear scheme represented below in Figure 10 to help commit contractors to cost controls early on. The discontinuity acts as additional motivation for managers to move early because only high effort throughout will get them to extra profits. Attempts to slack in the near term and make up ground later would make meeting the target appear substantially more remote *ex ante*. Similarly, when facing difficulties the scheme forces managers to implement cost controls earlier on, not only when on the precipice, to stop a significant loss from occurring. Besides encouraging cost controls, the government benefits because the contractor's potential profits are at all points lower than a linear scheme. Though the example in Figure 9 shows discontinuity only at one point on either side of the cost target, one can imagine similar structures that have multiple steps or are at some point lower and other higher than the linear scheme. Nonlinearity may also be applied to the PoP scheme discussed above on relatively immature system development contracts.

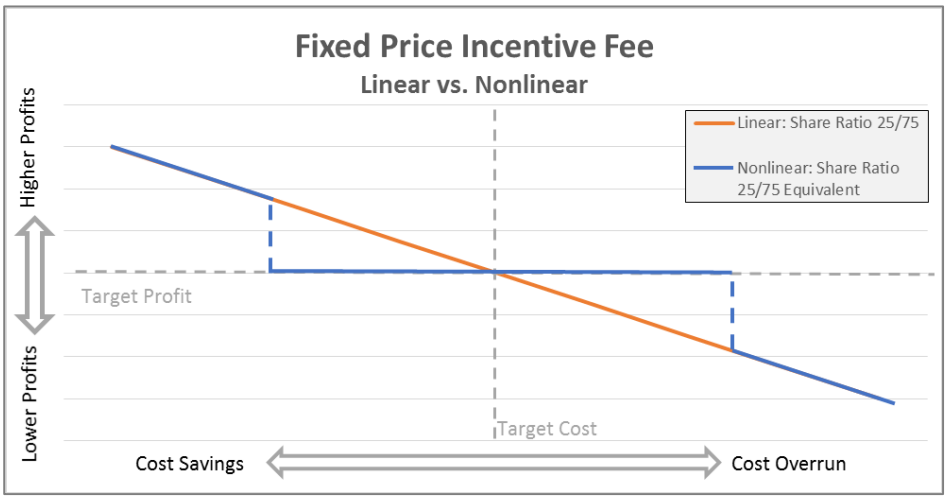


Figure 10: Example Linear vs. Nonlinear Incentive Structure in Fixed-Price Contracts

The commitment mechanisms discussed in this paper would be ineffectual without a culture change in which the government allows poor-performing contractors to wind down safely by allowing them to take losses. Such a plan can be executed by hindering further contract awards from certain business segments which experienced multiple cost overruns. This should not cause systemic problems because large prime contractors often have numerous facilities across unrelated business units. For example, Lockheed Martin has 518 locations across five primary units: Missiles and Fire Control; Aeronautics; Space; Information Systems and Global Solutions; and Mission Systems and Training.[38] The

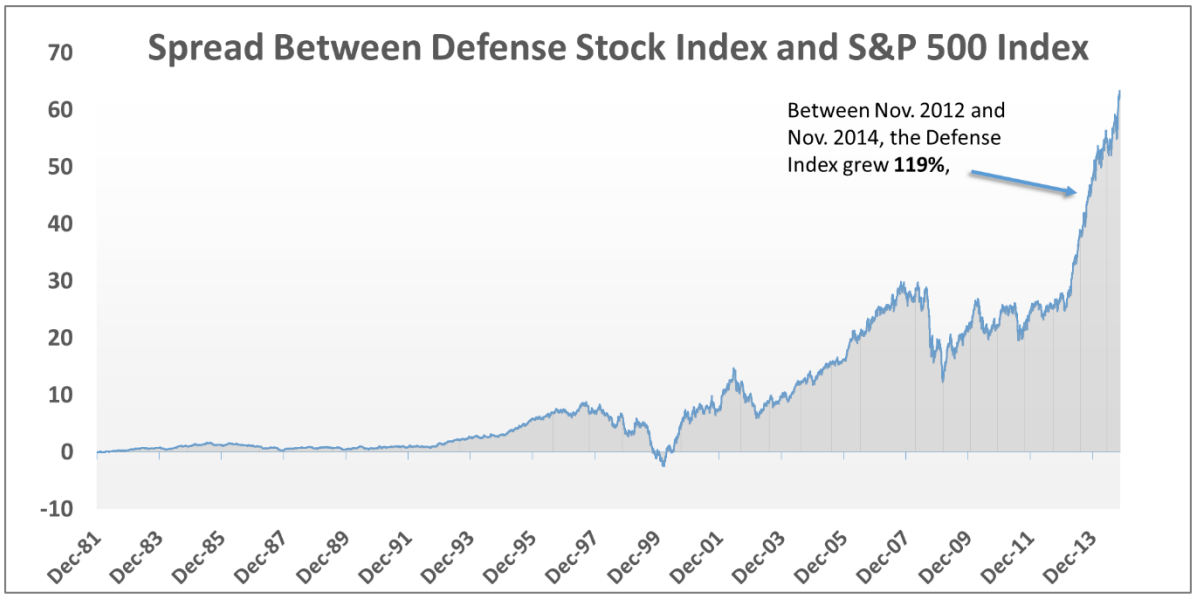
[38] SEC, Lockheed Martin Corporation 10-K Item 1 (2013).

Mission Systems and Training segment alone handles numerous disparate contracts including those for ships, submarines, helicopters, fixed-wing aircraft, sea and land-based missile defense, radar systems, simulators, and unmanned technologies.[39] In this business segment, Lockheed Martin did perform poorly on a system that is well outside its core competency, the Littoral Combat Ship (LCS), and the Navy stopped work on the second ship while cancelling the third.[40] But the government did not commit to the plan, and Lockheed's 2013 financial report cited increased volume in its Mission Systems and Training segment primarily coming from sales for the LCS.[41] One commitment schemes which may be applied will briefly be described. Realization of prior cost growth in similar products should be mandatorily considered when government agents evaluate proposals between contractors. The contracting community needs ready access to quality historical cost data so that institutional knowledge can inform decisions in the early stages. When losing contractors ask for a debriefing, these data can be used as rationalization.[42]

In conclusion, this paper has provided reasonable justification that both government agents and contractor management portray time-inconsistent behavior which can lead to poor contract performance and cost growth. The key insight from recent economic literature is the importance of commitment mechanisms to overcoming myopic behavior. Some rudimentary schemes have been suggested here, but there is much work to be done on not only providing robust evidence of hyperbolic discounting in defense acquisitions, but understanding which commitment schemes work best to overcome those issues. This is but one small part of a vast array of potential literature on the effects of human behavior and institutions on cost outcomes. The more realistic the assumptions or limited the possible number of states, the more a cost estimate can deliver actionable information independent of these considerations. But production processes are inherently open-ended systems with non-deterministic interactions, requiring cost estimating methodology to reflect analyses beyond those associated with traditional "engineering" problems. Because of the importance of defense markets to national interests, as well as their sheer scale, these matters deserve close attention.

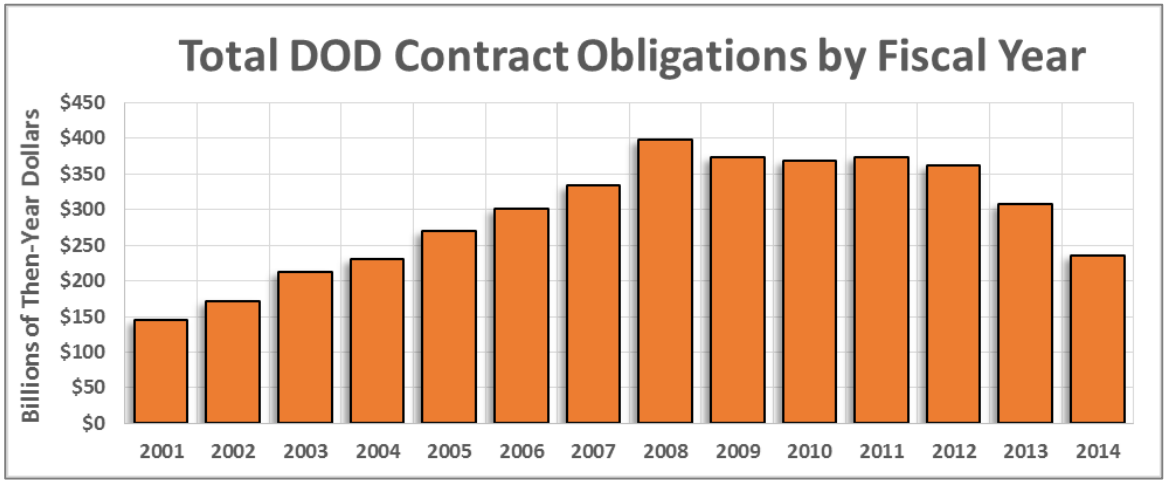
[39] SEC, Lockheed Martin Corporation 10-K Item 1 (2013).
[40] Merle
[41] SEC, Lockheed Martin Corporation 10-K Item 7 (2013).
[42] These Cost and Software Data Reports (CSDRs) are currently being introduced to defense contracting agencies, but largely as sources of historical profit rates as opposed to cost growth.

Appendix Figures:



Appendix Figure 1: Defense Stock Growth

***Source**: Yahoo! Finance datasets. Defense Stock Index includes equal weights Lockheed Martin, General Dynamics, Boeing, Northrop Grumman, and Raytheon. Spread calculated as Defense Index (1.0 = Dec. 31, 1981) minus the S&P 500 Index (1.0 = Dec. 31, 1981). Accessed Nov. 22, 2014.*



Appendix Figure 2: Defense Contract Outlays

***Source**: Office of Management and Budget (OMB), USASpending.gov.*

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