Technomics
Better Decisions Faster

Innovative Risk-Driven Contract Pricing Strategy

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Abstract

Effective contract pricing strategy helps *enable* the achievement of best *value-for-money* in defense procurement. But any strategy, to be effective, must align with exigencies of the development of production effort. There's no one-size-fits-all. More specifically, selecting a contract type, such as cost-plus or fixed price; a package of incentives (such as event- or calendar-driven); and share lines (above and below target) that are appropriate for a contract requires careful consideration, measurement and assessment of risk factors and uncertainties. These include:

- Stability of Requirements. Degree of firmness and completeness.
- Market Forces. Degree of competition.
- Maturity of Technology. Degree to which the platform and systems push the state-of- the-art, and are technically feasible.
- Contractor Readiness. Degree of contractor experience with the design and build of the same or similar systems.
- Price Validation. Extent to which a contract's target cost and price have been estimated independently, outside the influence of the project office or contractor.
- Schedule. Likelihood of failing to meet schedule plans and the effect of that failure.

This paper presents a scoring framework that *quantifies* the influence of these factors and, thus, provides a numerical basis for the determination of recommended contract geometry for upcoming procurements.

Table of Contents

Table of Figures

Table of Tables

1.0 Introduction

The U.S., the U.K., Canada, Australia, and other NATO and alliance partners routinely promulgate guidance on the establishment of contract parameters and contract geometries.[1] The guidance almost exclusively focuses on *cost-based pricing* where the defense marketplace is defined by oligopoly or even monopoly on the seller side and monopsony on the buyer side.[2] This is the reality of defense procurement today, *internationally*. The tenets of the guidance from whichever nation tend toward statements of general principles or *intent*, such as: use cost-plus contracts for high-risk procurements, use fixed-price incentive contracts for those of moderate risk, and use firm-fixed price for those of low-risk. These generic recommendations make perfect sense.

But, questions remain in implementing the guidance. For example, what *precisely* drives risk? Which *factors influence risk* and to what *degree*? What makes risk *high* versus only *moderately high*? How do you tell the difference? Is there a magic metric to employ? What's the *impact* of any *one* factor in driving overall contract and procurement risk? Which specific *elements* of risk should be addressed in the contract – to incentivize vendor performance?

This paper attempts to provide the answers, through an analysis of Navy programs, contracts, and Contract Line Item Numbers (CLINs), but with the model and results applicable for the other Services, too. The need has never been greater, as Figure 1 shows.

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[1] Examples include the U.S. DoD's *Contracts Price Referencing Guide* and the Federal Acquisition Regulation (FAR), particularly Part 15, "Contracting by Negotiation," and Part 16, "Types of Contracts." Another example is the Australian Government's *Contract Management Guide*, Procurement Policy Branch, Commercial and Government Services, Department of Finance, Australia, December 2020.

[2] Market-based pricing holds under conditions of robust, competitive procurement, which are increasingly rare. As noted by the U.S. Undersecretary of Defense for Acquisition and Sustainment, [USD(A&S); January 2022], "When markets are competitive, the Department reaps the benefits through improved cost, schedule, and performance for the products and services needed to support national defense. During initial procurement, incentivizing innovation through competition drives industry to offer its best technical solutions at a best-value cost and price. During contract performance, the expectation that contractors will have to compete against other firms in the future encourages them to perform effectively and efficiently."

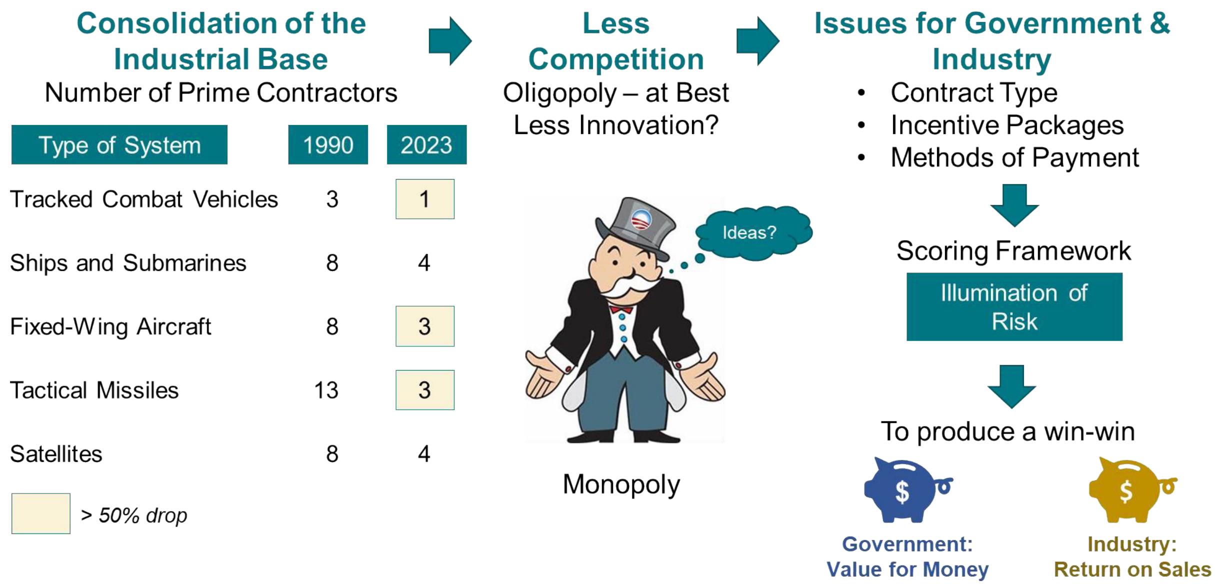

Figure 1: The Need for an Improved Contract Risk Model

Urgency: Align contract parameters with contract risk to achieve better outcomes

More than ever, sound, data-driven metrics are needed to better illuminate contract risk and engender more informed pricing strategies in the face of these challenges:

- Limited capacity and competition in the defense industrial base (DIB) in manufacturing urgently-needed military systems for Ukraine, such as the M142 High Mobility Artillery Rocket System (HIMARS);
- Massive consolidation in the DIB, within additional details provided in Appendix 1, which, in turn, increases vendor pricing power; and
- Continued cost-growth in major defense acquisition systems, as shown in Appendix 2.

On the first count, only Lockheed Martin manufactures HIMARS, with potential implications of any sole-source procurement highlighted in Figure 2. As noted by Dr. Bill LaPlante, USD(A&S), HIMARS is "… produced in Camden, Arkansas, in a big factory that used to be *literally a diaper factory*!"[3] With a sole-source producer of "St. HIMARS," as bloggers dub it, the efficacy of contract parameters lessens – adding to the need to review their selection and methods to incentivize the vendor.

[3] Transcripts from Getting Weapons into Production," 2022 Conference hosted by George Mason University and the Defense Acquisition University.

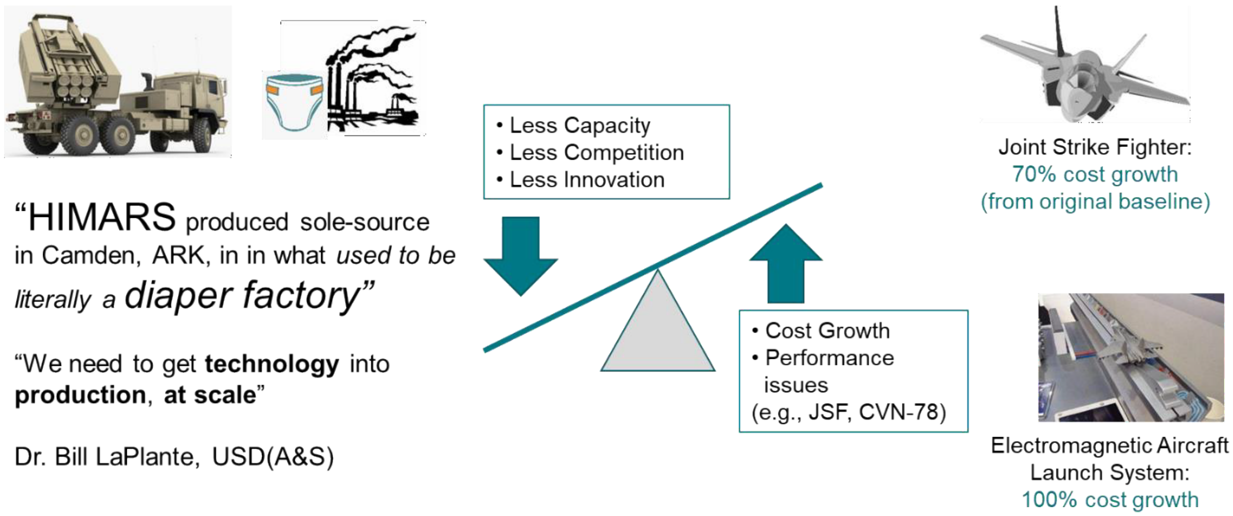

Figure 2: HIMARS Production for Ukraine

On the second count, the statistics are stark. Since the 1990s, the U.S. defense sector has consolidated substantially, transitioning from 51 to five aerospace prime contractors.[4] The number of suppliers for tactical missiles, fixed-wing aircraft, and satellites have all declined dramatically. More than 90% of missiles now come from just three sources.[5]

In the shipyard industrial base, the situational is arguably even worse from a competition perspective. Two companies, General Dynamics (GD) and Huntington Ingalls Industries (HII), own the five largest U.S. shipyards. Even in cases of so-called competitive procurement, considerations of maintaining the industrial base heavily influence the allocation of contracts between the big three East Coast yards, GD/Bath Iron Works (BIW), GD/Electric Boat (EB), and HII/Newport News Shipbuilding (NNS), and one Gulf Coast yard, HII/Ingalls.

Further, *only* HII/NNS builds aircraft carriers; *only* GD/EB and HII/NNS build submarines; and *only* Ingalls builds the U.S. Navy’s big amphibious attack vessels.[6]

Finally, second-tier shipbuilders such as Eastern, Halter Marine, and Austal often struggle with limited workload.

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[4] “State of Competition within the Defense Industrial Base,” Undersecretary of Defense (Acquisition and Sustainment), 2022.
[5] Ibid.
[6] The amphibious vessels include the LHAs, LHDs, and LPDs. The difference between Landing Helicopter Dock (LHD) and Landing Helicopter Assault (LHA) is mainly a matter of emphasis. Both have a full-length flight decks and utilize helicopters. The LHD mainly utilizes landing crafts to bring troops and equipment ashore while a LHA uses all or mostly air assets for the same mission. The Landing Platform Dock (LPD) vessels carries Landing Craft Aircushion Cushion (LCACs).

Given the *absence of robust competition* in the DIB, such as exists in other sectors of the global economy (e.g., the automobile industry or even the commercial shipbuilding industry), it's crucial to counter-balance industry's pricing power with carefully construed contract type and incentives – using the risk framework presented in this paper!

On the third count, cost growth remains an issue across the board in defense procurement. Notable recent examples include 100% cost growth for the Electromagnetic Aircraft Launch System (EMALS), and 20+% cost growth for both the CVN 78, USS *Ford*, and for the second ship in the class, the USS *Kennedy*.

This paper shows that the selections of contract types and incentive packages for some of these high-cost-growth procurements were of questionable efficacy – based on ex-post grading using the risk framework.

2.0 Contract Risk Management Framework

2.1 Objective

Defense contracts have frequently been conceived with *many disconnects* between the incentives that are designed and employed by the Government and the *motivational factors* that drive the contractor. These fundamental disconnects result in financial motivations that too often encourage contractors to expend extra effort on performance goals that are not important enough to the user to justify their increased cost, and that result in less-than-desired system interoperability, reliability, and sustainability.[7] The end result is an unsatisfactory outcome for both parties instead of win-win. The contractor falls short of achieving its targeted return on investment (ROI) and the government its expected value for money.

The contract risk management framework seeks to fix some of the misalignments through *illumination* of the *elements of risk* in the establishment of contract type, methods of payment, and incentives. More specifically, the scoring framework seeks to *quantify* risk from an ex-post numerical evaluation of the many factors that make or break a program and its contracts, such as the experience of the contractor, stretch in technology, solidity of requirements, and presence or absence of robust competitive procurement.

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[7] Examples of poor contract outcomes include Joint Strike Fighter with over 70% cost growth and Littoral Combat Ship (LCS), and its mine countermeasure module. The U.S. Navy's Remote Minehunting System (RMS), which was to be deployed from LCS, was cancelled due to poor effectiveness, poor reliability, and cost growth.

The benchmarks derived from the assessment of several dozen contracts across multiple programs serve to *inform* on-going and future development, design, and procurement efforts. This analysis, in turn, will help the government and contractor forge and maintain cooperative (win-win) relationships throughout the contracting process to ensure equitable returns for all parties while delivering systems *on-time*, *on-budget*, and that meet *effectiveness*, *reliability*, and *sustainability* threshold requirements.[8]

2.2 Elements of Risk

The pricing parameters of a contract are highly dependent on the nature of the procurement. For example, the contract type and package of incentives for a design and development contract for a next-generation fighter aircraft differ fundamentally from those of a steady-state production contract. The decision calculus, then, requires careful consideration, measurement and assessment of the *risk factors and uncertainties* which evolve as a program proceeds through the acquisition lifecycle. Importantly, some programs achieve stability much later than others. Joint Strike Fighter (JSF), for example, is still using low rate initial production (LRIP) contracts because achievement of full-operational capability remains elusive and the concurrent development contract was drawn out over the better part of two decades.

The contract scoring matrix specifies and assesses the elements of risk denoted in Figure 3 for each contract or CLIN in an acquisition program.

[8] Threshold requirements are must-achieve metrics in the U.S., validated by the Joint Chiefs of Staff (Joint Requirements Oversight Council, or JROC) for Major Defense Acquisition Programs. Failure of a system to meet its Key Performance Parameter (KPP) threshold/initial minimum rescinds the JROC validation, brings the military utility of the associated system into question, and may result in a reevaluation of the program or modification to production increments.

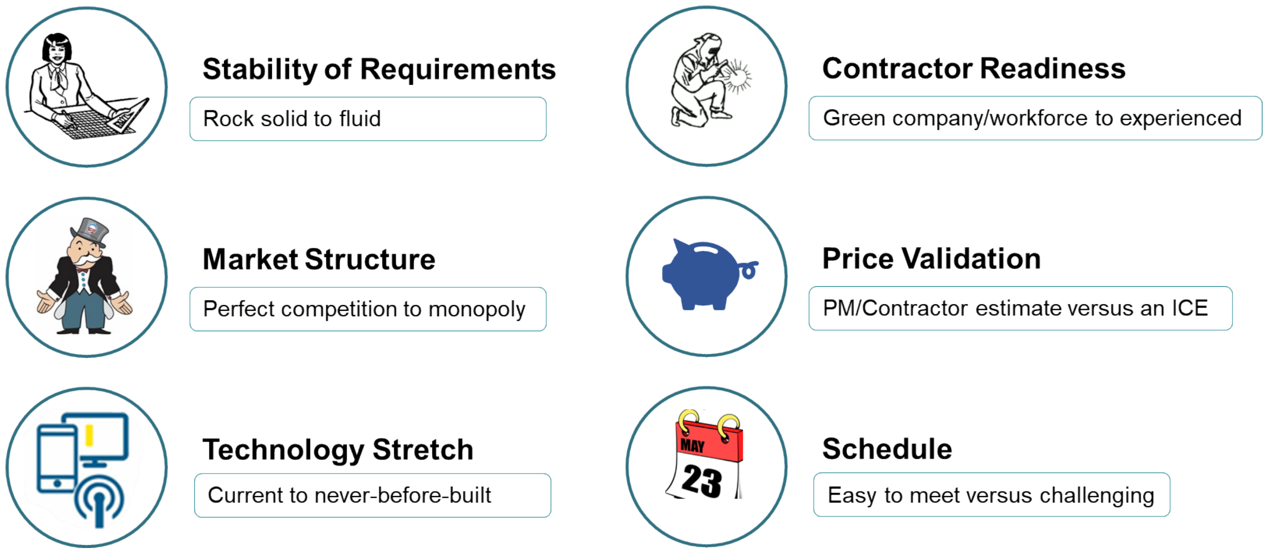

Figure 3: Elements of Risk

Sound pricing strategy requires illumination of the risks that influence results

- Stability of Requirements
  - Degree of firmness and completeness. Perfectly defined requirements are unique and unambiguous, complete and consistent, measurable, traceable, and verifiable (testable).
  - Risk results from as-yet-unseen changes in threat (i.e., "*we didn't fully understand or anticipate the problem*") or in design (i.e., "*we didn't fully understand the required solution*").
- Market Forces
  - Degree of competitive procurement.
- Maturity of Technology
  - Degree to which a platform and its systems are existing state-of-the-art and technically feasible, achievable, and obtainable.
- Contractor Readiness
  - Degree to which the company has experience with the design and build of the same or similar platform or systems.
- Price Validation
  - Extent to which a contract's target cost (both direct and indirect costs) and target price have been estimated by an independent authority outside the influence of the program office or the company.
- Schedule
  - Likelihood of failing to meet schedule plans and the effect of that failure.

3.0 Risk Scores

The Model uses a *weighted average* of scores for each of the elements of risk based on anchored, ratio scales. Each of these features (the *weights* and the *scales*) are discussed below.

3.1 The Weights

The contract risk factors are not equally important. There's no *a priori* reason they should be. And therein lies a problem in creating a valid scoring procedure using subject-matter experts. The opinions of practitioners vary according to their knowledge and experience. And as Arrow's *Impossibility Theorem* indicates, all techniques to rank-order preferences, other than using a dictator, will violate at least one commonly accepted measure of fairness.[9]

This research uses the highly regarded "Borda Count" technique to measure the *rank order* and *relative importance* of the risk factors, while recognizing that no flawless procedure exists for doing so.[10] Figure 4 presents a generic example.

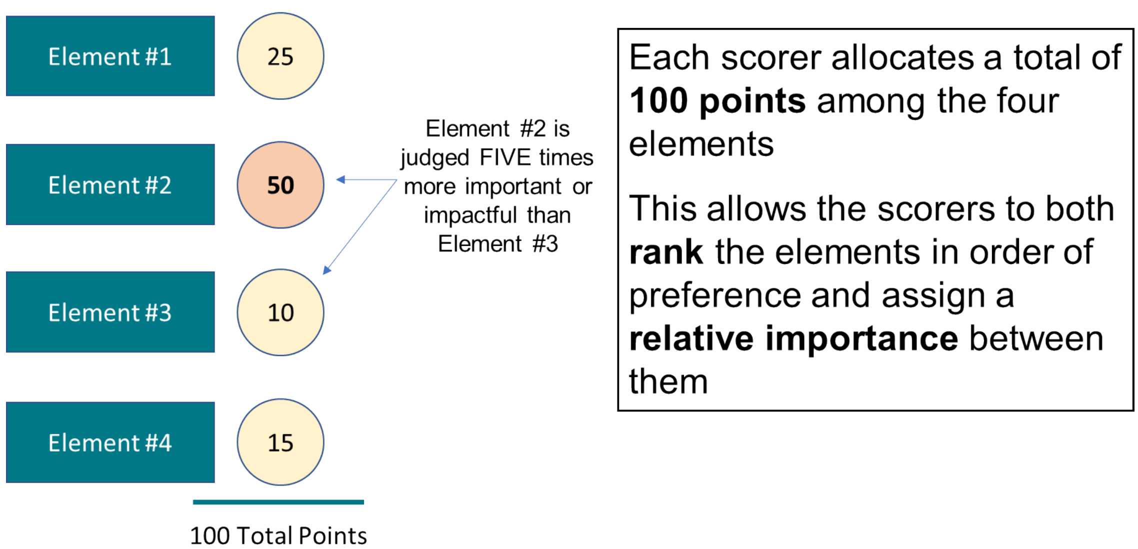

Figure 4: Borda Count Technique

[9] Arrow, Kenneth; "A Difficulty in the Concept of Social Welfare," Ph.D. dissertation, 1951.
[10] Major league baseball in the U.S. uses a modified Borda Count technique to choose its most valuable player.

Each scorer is given a total of 100 points to distribute among the factors or elements.[11] A score of 20, for example, means that the factor is judged to be *twice* as important or impactful as a factor with a score of 10. Consensus is achieved on the scores.

The Borda Count procedure contrasts with *ordinal ranking*. Ordinal numbers signify order or position. It's common in Analyses of Alternatives, for example, to use ordinal rankings and to represent them by numbers or letters, which are merely shorthand for category labels:

❶ represents *Best*; ❷ represents *Second Best*; ❸ represents *Worst.*

These rank orderings (1, 2, and 3) are *ordinal* not *cardinal* numbers, which express a *quantity*. Rank Order says nothing about the *value* of the score, only the *order* of the score. The numbers are merely shorthand for *Best*, *Second Best*, and *Worst*. The numbers could just as easily be letters such as *X*, *Y*, and *Z*, or *α*, *β*, and *γ*.

Unfortunately, it's an all-too-common occurrence in the U.S. DoD to perform numerical computations (arithmetic) on ordinal ranking. The result is *totally meaningless*. It would be equivalent to saying that 11 Ensigns in the U.S. Navy (each with an O-Rank of 1) exceed the authority of the Chief of Naval Operations (with an O-Rank of 10).

3.2 The Scales

In a similar vein, *ratio scales* are used to assess the risk and uncertainty of individual contracts associated with the programs and contracts. The scales rate the best case as 1.0, the worst case as 2.0, with with anchors provided in 0.25 increments.

In this scoring paradigm, a value of 1.50 represents 50% *more impact* or *risk* than a value of 1.00, and a value of 2.00 represents *twice* the impact. The use of ratio versus ordinal scales permits numerical manipulation of the scores using common arithmetical operations of addition, subtract, multiplication, and division.

The guideposts of 1.00, 1.25, 1.50, 1.75, and 2.00 in the framework serve to anchor the scores across programs and contracts. For example, the category "Maturity of Technology" refers to level of technological sophistication or advancement required of the prime or vendor *relative* to the current state-of-the-art. Any scores are allowed between the two "goalposts" of 1.00 and 2.00, with Technology Readiness Levels (TRLs) providing a useful gauge.

[11] This technique avoids the pitfall of cardinal ordering by measuring the *amount* by which one requirement or factor is judged more important than another. For more details, see "How to Use Rank Ordering for Comparison of Friendly COAs," Professors Downes-Martin and Volpe, 1 September, 2005, War Gaming Department, Unites States Naval War College.

- Minimum Risk
    - The lowest score of 1.00 indicates that all or most technological requirements have been achieved on an identical item currently or previously in production by the prime contractor. In this case, few, if any, changes to the item (a system, component, or the platform itself) are required. No significant integration, weight, or size issues need to be addressed.
- Maximum Risk
    - The highest score of 2.00 represents new technology. That is, the item in question is significantly beyond the current state-of-the-art. A new approach or concept is necessary to achieve the system requirement. In addition, the new concept has yet to be demonstrated, even in a laboratory environment. Unprecedented integration, weight, and size issues may have to be resolved before the system can meet operational requirements.

4.0 Model

4.1 Domain

The team assessed risk for 39 contracts within the domain of U.S. ship and ship-system design and construction programs. The choice of the programs within the broad domain was based on the team's collective *hands-on* experience in generating cost estimates and analyses in support of both senior shipyard and U.S. Navy leadership. The experience included cost analysis support on surface combatants and amphibious vessels (for a private-sector company) and support to senior Pentagon officials on Remote Minehunting System, *Zumwalt Class* surface combatants, and *Ford Class* carriers.

The authors took pains to avoid selection bias when establishing the content of the sample. Contracts were selected from *each* of the major shipyards in the U.S. industrial base today.

4.2 Weights

The team first established the risk-and-uncertainty weights shown in Figure 5, leveraging decades of experience in cost analysis, and using the Borda Count technique.

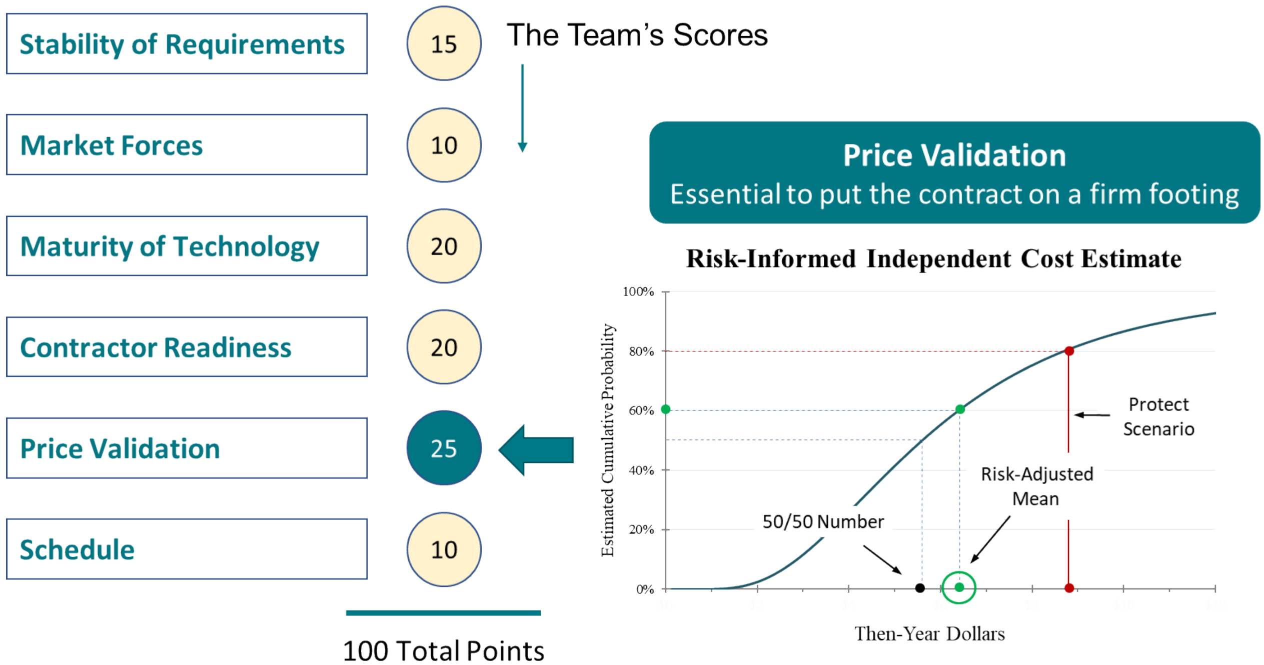

Figure 5: Risk Weightings

Interestingly, price validation was deemed the most important element of contract risk, perhaps due to the experience of team members with an entire spectrum of contracts and contract outcomes, where the *quality* and *independence* of the cost estimate proved essential in the establishment of a sound baseline.

4.3 Scoring Matrix

The scoring matrix uses *anchored* scales, with an example illustrated in Figure 6 for Market Forces, and with details presented in Table 1. The anchors are pre-defined benchmarks that are set at various points in the range of values (1.0 to 2.0) to increase the objectivity of the scoring.

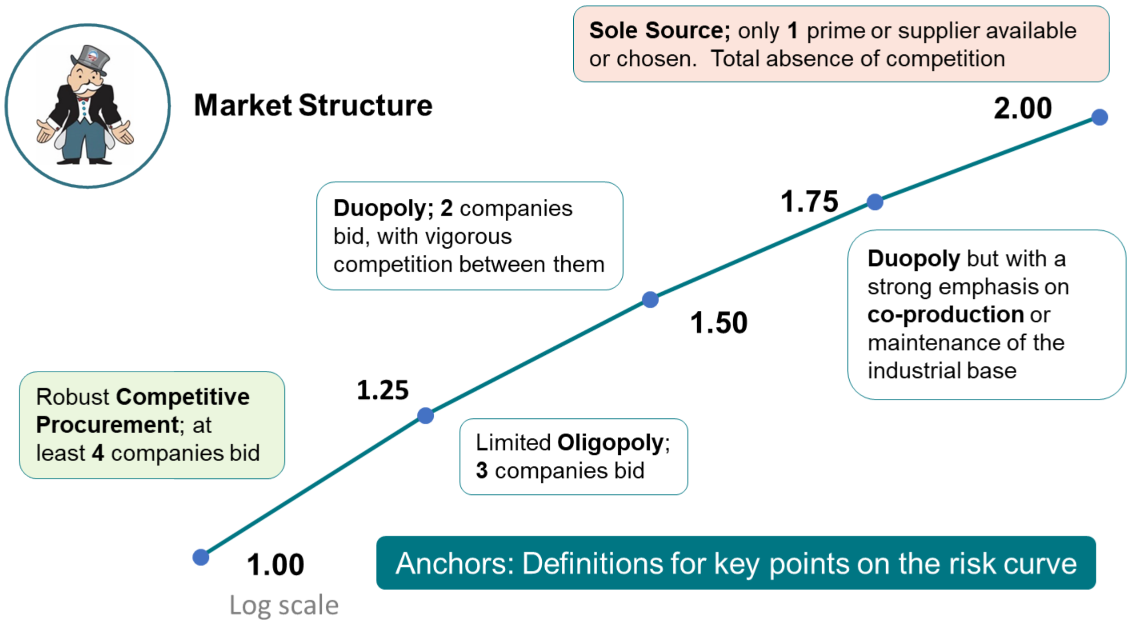

Figure 6: Anchored Scales

A value of 1.00 is associated with robust competition, with four or more companies bidding for the work. A good example is the Navy's design and build contract for FFG-62 *Constellation Class* frigates, where four industry teams submitted different designs and prices.

A value of 1.50 is associated with a type of duopoly where there is vigorous competition between the two firms. It represents 50% more risk than the baseline value of 1.00, using the ratio scale. Duopoly in the defense market sometimes takes the form of allocation of work between the two firms to manage the industrial base (e.g., surface combatants for the Navy). The risk consequently higher (a value of 1.75).

Finally, a maximum value of 2.0 occurs in a sole-source environment, such as design and construction of aircraft carriers, where only Newport News Shipbuilding does the work.

Table 1:Scoring Matrix for Scoring Individual Contracts

Category	**Weight**	**Scoring Scale**				
		1.00	**1.25**	**1.50**	**1.75**	**2.00**
Stability of Requirements	15%	Requirements are well defined and understood before a project is approved to start development	So-called "normal" or expected changes in engineering change orders (ECO's) and in procurement quantities	Threshold and objective values for system capability somewhat flexible between gates	Significant requirements creep projected due to the nature of an emergent threat	Requirements are highly unstable; high probability of re-set
Market Forces	10%	High degree of competitive procurement: at least four primes or suppliers bidding on the work (oligopoly)	Competitive procurement with three primes or suppliers bidding on the work	Duopoly - two industry teams or two primes, with vigorous competition between them	Duopoly with a strong emphasis on co-production or need to maintain the contractor industrial base	Sole-Source - only one contractor available or chosen for the work. Total absence of competition
Maturity of Technology	20%	Fully mature. Existing state-of-the-art from an industry perspective	Minimum advancement required (TRL 7 or 8)	Modest advancement required (TRL 5)	Significant advancement required (TRL 2 or 3)	Brand new technology - never before built
Prime or Vendor Readiness	20%	Extensive experience with building the platform or system – almost identical	Experience with similar platforms or systems (≤ 20% change)	Experience with analogous platforms or systems (21% to ≤ 40% new)	Little experience with the platform or system (41% to ≤ 60% new)	A new type of platform or system; no known design or construction experience
Price Validation	25%	Independent Cost Estimate (ICE) by an experienced organization with a proven track record	ICE but <u>without</u> independent estimates of labor and material escalation, and with a pass-through of overhead rates	Use of independent cross-checks and factors for high-dollar value components of the WBS: Independent Cost Assessment (ICA)	Assessment and adjustment of the contractor estimate	Reliance on framing assumptions and estimates from the contractor - without an assessment of their validity
Schedule	10%	Easily achievable - durations firm with few dependencies. Long-lead material in place. Experienced workforce	Achievable	Somewhat challenging	Challenging	Very challenging - many task/schedule dependencies. Highly stochastic task durations. Material not in place. Green labor

4.4 Example

Using the anchored scales and weights of the table, the team scored each of the 39 contracts. The LPD-17 *San Antonio* Class lead-ship Detailed Design and Construction (DD&C) contract provides a good example.

The contract type was originally cost plus award fee (CPAF). It was then then changed to cost plus incentive fee (CPIF) as technical problems emerged and cost growth became egregious – eventually reaching 100%, as Figure 7 shows.[12]

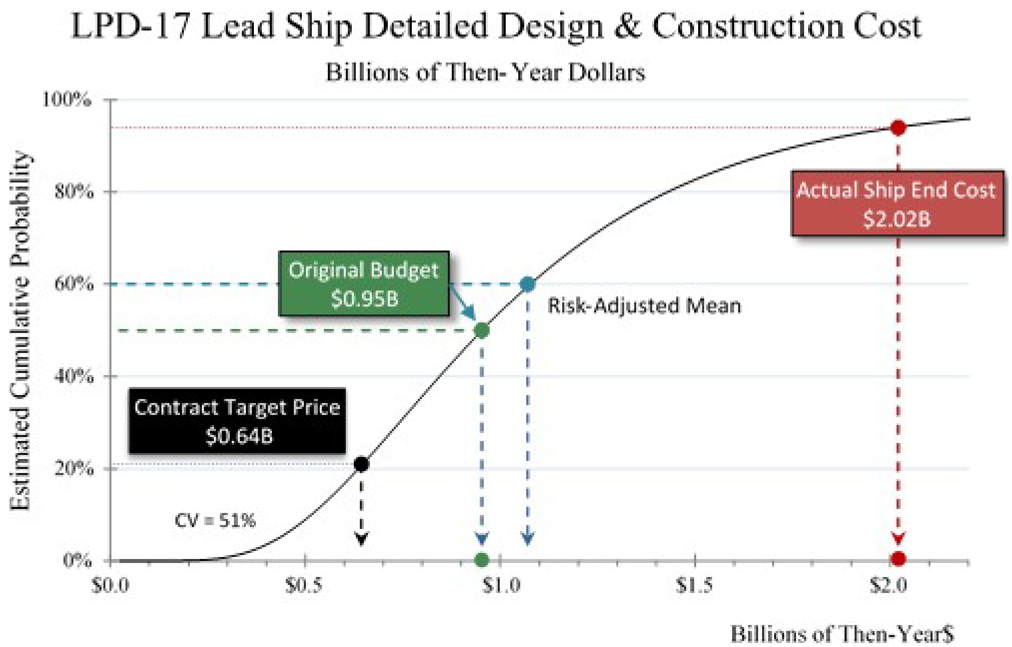

Figure 7: LPD-17 Cost Growth

In aggregate, the risk score for the lead-ship (USS San Antonio) contract was 1.71, as Figure 8 shows, or 70% higher than a no-risk baseline case. Note the maximum-risk score of 2.00 for Price Validation, as the program office bought into the shipyard's framing assumption that they'd be at unit #4 on a learning curve – from the get-go, due to computer aided design (CAD) and co-location of the contractor and government management offices in New Orleans. The latter had no positive effect and the CAD software bombed. Additional details of the scoring are presented in Appendix 3.

[12] Problems persisted through the next five contracts. The Naval Sea Systems Command (NAVSEA) chose not employ a fixed-price incentive (FPI) contract on the program until LPD-22.

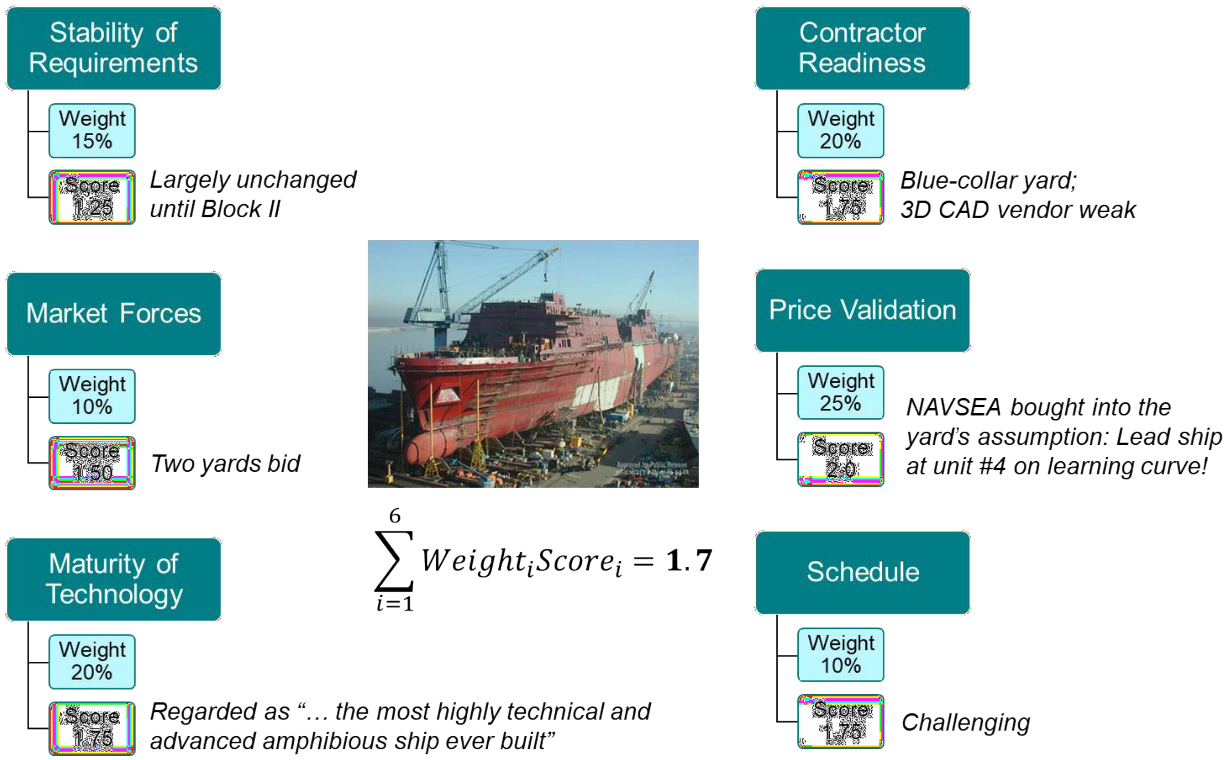

Figure 8: LPD-17 Lead-Ship Design and Construction Contract

4.5 Summary of Contract Risk Scores

Table 2 summarizes results of the scoring, with Appendix 4 presenting numerical details for each contract. The value of 1.70 stands for Market Forces stands out. It's a reflection of a current concern of the Undersecretary of Defense for Acquisition and Sustainment; namely, diminished competition in the defense marketplace.

	Stability of Requirements	Market Forces	Maturity of Technology	Contractor Readiness	Price Validation	Schedule	Aggregate Weighted
Average (μ)	1.40	1.70	1.44	1.46	1.46	1.50	**1.47**
Std Dev (σ)	0.22	0.34	0.28	0.27	0.24	0.23	**0.18**
CV (σ/μ)	15.9%	20.0%	19.5%	18.3%	16.7%	15.2%	**12.5%**

Table 2: Summary of Contract Risk Scores for U.S. Naval Contracts

The scores represent useful benchmarks for judging contract risk for programs and contracts, both ongoing and future. Remarkably, the aggregate risk score is about 1.5, or the midpoint between no risk and maximum risk. The CV's show a marked consistency between the different categories of risk. Interestingly, the aggregate CV of

12% is lower than any of the individual category values, indicating that pluses and minuses tend to offset each other.

Key take-aways at the macro level include:

- Stability of Requirements. Capability-based planning is the gold standard in the U.S. and other NATO nations and alliance partners such as Australia. That said, requirements are never known with perfect certitude nor perfectly translated into ship technical and performance requirements. Requirements *churn* influenced the selection of contract types on programs such as DDG-1000, Littoral Combat Ship (LCS), and Remote Minehunting System (RMS). The values of 1.4 and 1.5 accord closely with moderate risk and uncertainty.

- Market Forces. The lack of robust competition has been and remains a problem for the Office of the Secretary of Defense and for the Services. The U.S. DoD generally but not always competes contracts for ship conceptual design and lead-ship design and construction. However, once a shipyard is selected for the work, they become a de-facto sole source. Hence the value of 1.7 for Market Forces. This phenomenon holds for other platform categories, too.

- Maturity of Technology. The aggregate score of 1.44 indicates moderate risk. Indeed, the Weapon Systems Acquisition Reform Act (WSARA) of 2009 strove to reduce risk in acquisition through, among other factors, stressing the development of prototypes early on. However, outliers occur, such as the previously mentioned LPD-17, with a risk score of 1.7 for technology immaturity. The practical reality is that the lead ship is generally a hybrid of a prototype and a proven operational model (cf. CVN-78). Even where engineering development models (EDMs) are untaken to reduce risk with good intentions, the program can go overboard with too much simultaneous unproven technology, as in DDG-1000.

- Contractor and Vendor Readiness. Not surprisingly, the major U.S. shipyards with their long history of building the most complex military vessels in the world score well in terms of experience or fit, on average, with a value of 1.46. But, again, note the outliers. A classic example, as mentioned above, is Avondale Industries. The yard had never constructed a vessel of the complexity of LPD-17. Consequently, a good part of the work had to be transferred to Ingalls (a yard experienced with designing and building surface combatants) to complete the effort. (As a sad postscript, Avondale ceased construction of naval vessels after Hurricane Katrina.)

- Price Validation. For major weapon-system acquisition projects, the U.S. DoD produces Program Office Estimates (POEs), Component Cost Positions (CCPs), and Independent Cost Estimates (ICEs), with the latter usually performed by the Office of the Secretary of Defense (OSD) Cost Assessment and Program Evaluation (CAPE). This thorough and complete review process produces a risk score of 1.46, indicating good results, on average. But, yet again, there are outliers, such as LPD-17 for which Navy acquisition officials bought into an erroneous framing assumption from the shipyard. The assumption, which proved blatantly false, was that the lead ship would come in at a unit price normally found at the 4th unit on a learning curve – due to the efficiencies of computer-aided design (CAD) and collocation of the program office with the shipbuilder.

- Schedule Challenge. The challenge in meeting schedule is heavily influenced by the maturity of technology and contractor readiness to perform the work. On average, the U.S. ship construction programs fare moderately well.

5.0 Program Insights

Take-aways gleaned from the individual project scores related to contract types, contract incentives, and methods of payment include:

- Effectiveness of Pricing Approach. The contract type is usually cost-plus (or a hybrid such as CPAF, CPFF, CPIF) for conceptual design, DD&C, and for the development of new technologies. The contract type then tends to become fixed-price for follow-on contracts. The effectiveness of the pricing approach in motivating the contractors is difficult to discern clearly, with these examples illuminating some of the issues:

  - **LSD-41 Class Ships**. The contract for LSD-41 lead ship construction was originally CPAF. It was converted to CPFF (with ceiling) based on forecasts that the yard would significantly overrun target cost. The contract for LSD-42 was also CPAF. It was converted to FPI with a 50/50 share line and 123% ceiling due to poor contractor performance. In any event, moderate cost growth ensued for both contracts.

  - **LPD-17 Class Ships**. The original contract type was CPAF based on controlling Total Ownership Cost (TOC) of the vessels, or, more specifically, future *maintenance* costs. In the face of cost growth, however, NAVSEA renegotiated the contract. It changed the contract type

from CPAF to CPIF, with the incentive fee tied to controlling *construction* costs.
    - Nevertheless, the lead ship experienced 100% cost growth
    - Further, because of egregious technical and performance issues, the government needed to use cost plus for five ships before changing to FPIF; that said, cost growth and schedule delays slowly but steadily decreased.

  - **CVN-78 Class Ships**. The contract type for CVN-78 was composed of multiple cost reimbursable type contracts, including a massive Construction Preparation (CP) contract, circumventing full funding rules. This was advantageous for the U.S. Navy given immature technologies and poorly defined requirements, and it gave the yard (Newport News) the chance to reduce cycle times, maintain schedule, and maximize efficiency. The contract type for CVN-79 was fixed price incentive fee.
    - In general, FPIF is appropriate *only* when requirements are stable and technologies are mature. This was *not* the case with CVN-79, with the lead-ship (CVN-78) having been delivered at only 80% complete.
    - The contracts for the Electromagnetic Aircraft Launch System (EMALS) and Advanced Arresting Gear (AAG), both crucial for achieving planned aircraft sortie rates, were cost-plus. Cost growth reached 100% on the former. Production units were priced using fixed-price contracts. This pricing approach was effective only because cost growth was captured in the development contracts, absorbed fully by the government.

- <u>Effectiveness of Performance Incentives</u>. Incentives can be a beneficial tool in controlling contractor and vendor behavior. But the ability of fixed-price incentives to shape outcomes is a dubious proposition when new technologies are present. A good practice seems to be using FPIF or FFP contracts only *after* risks have been mitigated. Many of the projects in the sample do exactly this, but the following a classic counterexample.
  - **Remote Minehunting System**. The contract was cost plus for development. Contracts were then awarded for Lot 1 and Lot 2 production using a fixed-price incentive strategy even though the RMS *could not meet* reliability thresholds. The incentives under production did not have their intended effects, and the project was eventually cancelled.

- Price Validation. Price validation has the highest weighting amongst the six factors that influence overall contract risk. The U.S. has performed poorly in estimating ship and ship-system costs, as Appendix 2 shows. No matter what the contract type and incentive structure, poor results are likely to result in the absence of a realistic, accurate, and complete cost baseline, with risk accounted for. Put another way, overruns relative to unrealistic contract target costs cannot be entirely blamed on poor *performance*.
  - Examples of poor *estimates* include LPD-17 lead and follow-on ships, EMALS, AAG, and RMS.

- Efficacy of the FPI Strategy. There's no evidence to suggest that one type of contract or set of contract performance incentives uniformly and consistently produces better outcomes than any others. The U.S. DoD advocates the use of fixed-price incentive contracts early-on, with 50/50 share lines.[13] However, each project is a non-repeatable experiment. Each is unique. Upfront flexibility and realism are critical in trying to influence the contractor to better manage the costs, schedule, and quality of the project. The government should be realistic when choosing a contract type. (In particular, FPIF contracts with a 50/50 share line and 120% ceiling price are patently *unrealistic* for most Development contracts, as will be demonstrated in Appendix 5.)

- Value of Flexibility.

For each CLIN, the contract type and set of incentives should align with the risk profile of the framework, and with the project and contract scores representing invaluable benchmarks for future acquisitions.

  - If risk is high, then an economic analysis or analysis of alternatives (cost and capability) should reflect that risk and laser-focus on the importance of any new technology.

  - When using incentives, the contractors should reap their benefit *only* if the original goals were met, and not prematurely (as in the case of the Remote Multi-Mission Vehicle (RMMV)) for the U.S. Navy's Remote Minehunting System. Incentives should not be awarded to cover additional costs incurred by the contractor that were not in the original estimate. Again, this is an important lesson from RMS, where the contractor was paid several hundred million dollars in additional

[13] Better Buying Power 2.0; Secretary Frank Kendall, USD(AT&L).

expenditures to correct faulty work. Once technologies are mature enough that the risk profile supports FPIF or FFP contract types, then the fixed-price award should be used *after* the completion of a development contract.

- In this fashion, without the presence of active, on-going development contract, the risk of cost overruns becomes the burden of the contractor or vendor, and not the government.

- When the government finally decides to move to a FPIF or FFP contract type, then the development contracts should be complete or near complete. These fixed-price contract types should not be available to the contractors as a source to cover any subsequent cost growth, if and when it occurs. This would only serve to de-incentivize the vendor.

- <u>No Guarantees</u>. The use of any particular contract type or set of incentives is no guarantee of success. The use of an FPIF contract, in theory, shares overrun risk between the government and the contractor. But, in reality, risk does not decrease in many cases because of an immature design. While the contractor may be incentivized to control cost, the technology/design issues can overwhelm even the best intentions of program managers.
  - A best practice is to use cost-plus contracts for targeted new technologies or in cases where the contractor is inexperienced.

- <u>Uniqueness of a Program</u>. A best practice is to treat each contract within a program as an individual action, based on its specific risk profile and not broad guidance. That is, influence the outcome by making decisions based on a particular situation or set of circumstances. In the U.S. DoD, and particularly the Department of the Navy (DON), there is an enormous amount of institutional or cultural bias to overcome in awarding certain contract types for certain technologies. The Navy has historically used FPIF contracts for shipbuilding. The Navy's FFG-62 DD&C contract is a good, recent example. If substantial risk is present, the choice is questionable. Focus acute attention on the use of concurrent development and production contracts.
  - CVN-79 and RMS contracts are good examples of concurrence that resulted in unintended consequences – program perturbation and the failure of incentives to work.

- Alignment with Industry Best Practices. Shipyards such as Fincantieri build both commercial and military vessels. On the commercial side, in their construction of cruise vessels at their yards on the Adriatic, they take great pains to eliminate as much risk as possible. They focus on perhaps one innovation at a time, and test the effectiveness of the new system (in concert with the buyer) before proceeding with ship construction.
  - Implementing best practices for defense projects, however, is very difficult due to the changing nature of the threat and the exacting requirements that follow.

- Contractor Motivation. There's an inherent tension between incentive provisions in development and low-rate production contracts versus cross-contract incentives downrange, as Figure 9 shows.

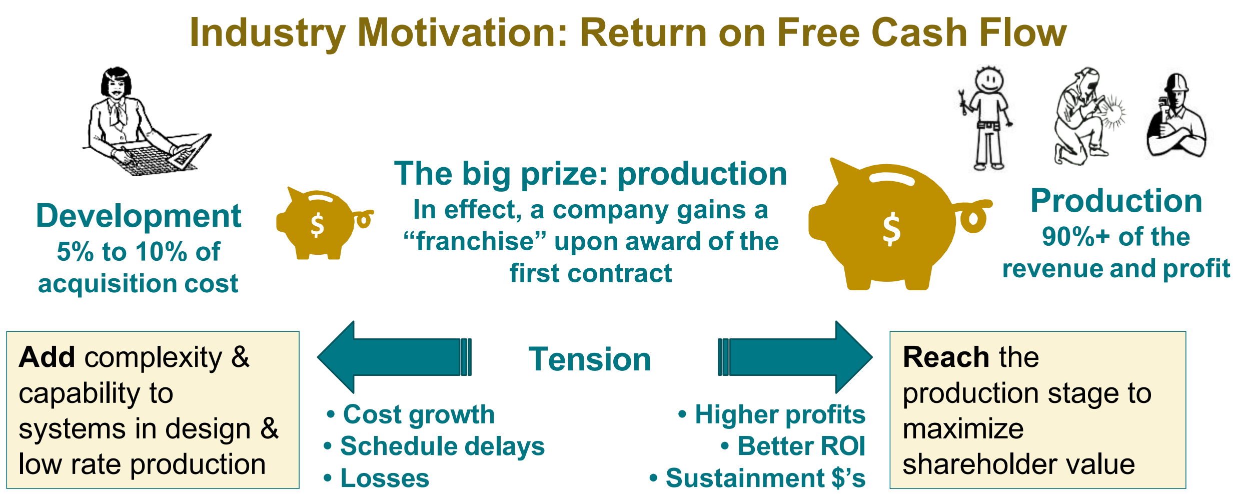

Figure 9: Cross-Phase Contract Tensions

Given the cost of designing and developing complex weapon systems, coupled with limited competitive procurement and the cost of bringing onboard a second source, a company's winning bid early-on (say at Milestone B) often implies the award of a "franchise" for the entire acquisition phase, and even into sustainment. This dynamic can and does impact a firm's strategic pricing perspective. If the firm adds complexity and capability to early design, it likely achieves higher unit price downrange. Examples are Joint Strike Fighter and DDG-1000 *Zumwalt Class* ships, or the "eight-billion-dollar boat," as it's sometimes dubbed. On the other hand, the additional complexity (especially if price validation is poor) increases the likelihood of cost growth, schedule delays, and contract losses during development.

A contractor's prime motivation is arguably to maximize the free-cash-flow return on invested capital for all contracts across all projects in the portfolio. This profit motive might induce the firm to trade short-term losses for future gains, and could easily swamp the incentives of development contracts.

- Best Approach. Approaches, strategies and practices for future procurements include:
    - Assess the risks of the project and contract using the framework presented above.
    - Specifically, adjust the content of the contract, and set financial parameters, accordingly:
        - If Technology Maturity is high-end risky, consider moving the tasks into block upgrades rather than inclusion in the baseline
        - If Market Forces is too high, focus attention on more competition at the Tier 1 vendor level, if feasible
        - Perform government Independent Cost Estimates (ICE's) early-on to validate costs
            - Make risk analysis and cost/capability tradeoffs (the knee in the curve) part of the analysis.

6.0 Operational Construct

The risk-scoring framework provides an analytical basis to support internal government and government-contractor deliberations on upcoming ship design and construction contracts. Application of the framework will help engender better-informed decisions related to choices of contract type and incentives – with the ultimate goal of increasing the effectiveness of the pricing approach at acceptable cost and risk to all parties.

The first step in making the framework operational is to *establish a team* to score the upcoming project/contract(s), with representation from the requirements, engineering, and contracting communities. Participation by the contractor might be beneficial, too, per the discretion of government acquisition authorities. A cross-discipline approach helps ensure that all sources of risk are assessed thoroughly from a 360-degree project-management and execution perspective.

Conduct a formal scoring session according to the following steps.

6.1 Collect Intelligence

Prepare for the scoring session by collecting information pertinent to choosing the contract types and incentives of the upcoming contract.[14] Data includes requirements documents, programmatic information, metrics on past contractor performance (including cost growth, schedule slippages, and cash flow), and benchmark risk scores as presented in this paper.

Obtain the *details* of risk scores for *best-fit analogies* – to include not only the raw numbers but the *rationale* behind them.

6.2 Evaluate Evidence

Share and *explain* details of the upcoming contract to the group of scorers to help ensure a minimum-common-denominator degree of understanding. Vigorous open discussion of prospective values of category weights and risk scores will strengthen the integrity of the exercise.

6.3 Establish Weights

Establish the weights of each of the six risk categories in a formal scoring session, where: there are *k* participants who make individual choices: w_1 = the weight for Stability of Requirements; w_2 = the weight for Market Forces; …; and w_6 = the weight for Schedule Challenge.

Expanding this notation, the second subscript in the term w_{1i} represents the input from the i^{th} scorer for the first weight. That is, w_{11} is Scorer #1's input for weight w_1, w_{21} is Scorer #1's input for weight w_2, and so on.

Compute first and second moments (mean and variance) of the probability distribution for scoring the weights accordingly

<u>Means</u>:

$\mu_{w1} = \sum_{i=1}^{k} w_{1i}$ or the average value of the first weight, w_1, across the *k* scorers

$\mu_{w2} = \sum_{i=1}^{k} w_{2i}$ or the average value of the second weight, w_2, across the *k* scorers

:

$\mu_{w6} = \sum_{i=1}^{k} w_{6i}$ or the average value of the sixth weight, w_6, across the *k* scorers

[14] This step is akin to the military function of "Intelligence Preparation of the Battlespace."

Variability:

σ_1 = standard deviation of the *k* scores for the first weight, or the observations $w_{11}, w_{12}, \ldots, w_{1k}$.

σ_2 = standard deviation of $w_{21}, w_{22}, \ldots, w_{2k}$, and so on.

Coefficients of Variation:

$CV_1 = \sigma_1/w_1$, $CV_2 = \sigma_2/w_2$, …, $CV_6 = \sigma_6/w_6$.[15]

The *mean* estimate of each weight is a measure of its *relative importance or influence* within the set of six categories of risk (e.g., Stability of Requirements versus Schedule versus Price Validation). A *CV*, on the other hand, is a measure of *degree of consensus* in the assessment of influence. The lower the *CV*, the stronger the consensus, and with a value of zero indicating unanimity.

For example, the mean estimated weight μ_{w1} for Stability of Requirements might be 20%. But the *uncertainty* of this estimate might be *relatively* high, with a *CV* of say 50%, compared to the other five *CV's* ranging from, say, 15% to 25%. The 50% *CV* represents a significant *difference of opinion* amongst the scorers. This might be due to factors such as scorers' unique perspectives or varying degrees of knowledge and experience. Additional group discussion in such cases will pay dividends in terms of a richer understanding of the risks that influence contract outcomes.

6.4 Score the Contract

With *category weights* established using mean values $(\mu_{w1}, \mu_{w2}, \ldots, \mu_{w6})$,[16] the next step is to generate a score for each of the risk categories for the upcoming contact, using ratio scales from 1.0 to 2.0, with anchors provided in 0.25 increments, as proposed in this study. The mathematical procedure is the same as scoring the weights; i.e., compute means, standard deviations, and *CV's*.

6.5 Actionable Intelligence

The scoring results represent *data-borne information* or *actionable insight* that helps improve the effectiveness of pricing strategy by illuminating elements of risk that influence outcomes. Better understanding of risk, in turn, leads to better selections of contract types, incentives, and methods of payment.

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[15] A *CV* is a probability distribution's standard deviation divided by its mean. CV's can be thought of as the reciprocal of a signal-to-noise ratio. They are independent of unit of measurement, allowing for comparisons across probability distributions, which in this case are those for the six risk categories.

[16] It is left as an exercise to the reader to show that the six mean values will sum to 100%. (Even if they didn't, they could be normalized to do so.)

The scoring results inform choices for the upcoming contract based on the following:

- The aggregate or total-contract risk score
- The Impact Factors of each of the risk categories
- A comparison to benchmarks such as averages and analogies.

An Impact Factor is similar to a Beta coefficient in regression analysis – it allows comparisons of the *effect* of risk scores, across the six categories, on a contract outcome. The higher the Impact Factor, the more influential is the element of risk.

$$\textbf{Impact Factor} = \textbf{Category Weight} \cdot \textbf{Risk Score.}$$

In the notional example of Table 3, two Impact Factors stand out, Contractor Readiness and Schedule Challenge. They influence the degree of overall contract risk more than any of the other elements, or 43% in total.

Table 3: Notional Scoring of Contract Risk

	Notional Scoring of Contract Risk						
Risk Categories	**Stability of Requirements**	**Market Forces**	**Maturity of Technology**	**Contractor Readiness**	**Price Validation**	**Schedule Challenge**	**Aggregate Score**
Category Weights (Means from Scoring)	μ_{w1} **15%**	μ_{w2} **10%**	μ_{w3} **15%**	μ_{w4} **20%**	μ_{w5} **20%**	μ_{w6} **20%**	**100%**
Evaluation of Upcoming Contract							
Mean Scores	1.50	2.00	1.85	1.80	1.35	1.83	**1.70**
CV	*18%*	*25%*	*19%*	*15%*	*20%*	*15%*	
Impact Factors	0.23	0.20	0.28	0.36	0.27	0.37	**1.70**
Percent of Total	13%	12%	16%	21%	16%	22%	**100%**
U.S. Shipyards							
Means	*1.40*	*1.70*	*1.44*	*1.46*	*1.46*	*1.50*	***1.47***
CV	*16%*	*20%*	*19%*	*18%*	*17%*	*15%*	***12%***

This is *actionable intelligence* which addresses *where to apply* incentives to *diminish project risk* using contract types such as cost-plus award fee (CPAF), cost-plus incentive fee (CPIF), and fixed priced incentive (FPI). For maximum leverage, it is better to apply incentives for the "big-ticket," more impactful elements of Schedule and Readiness rather than the "lower-hanging fruit," less impactful elements of Requirements and Market Forces, in the notional example.

- <u>Schedule</u>. Impact factor of 0.37. Reduce risk by rewarding the shipyard to meet schedule using metrics such as the following:
    - Threshold and objective calendar dates for each incentivized milestone

  - Design milestones such as a preliminary design review and critical design review
  - Construction milestones such as percent complete.

- Contractor Readiness. Impact factor of 0.36. Reduce risk by rewarding the shipyard to improve readiness using metrics such as the following:
  - Percent complete for (detail) design prior to commencement of construction
  - Percent vacant jobs filled for hard-to-fill professions and trades such as naval engineers and electricians
  - Demonstrated improvements to manufacturing processes.

The risk elements of Maturity of Technology and Price Validation might be addressed, too, as secondary considerations, since each represents 16% percent of total impact.

- Maturity of Technology. Reduce risk by incentivizing the shipyard to do the following:
  - Achieve incremental improvements to Technology Readiness Levels (TRLs) and Manufacturing Readiness Levels (MRLs) according to plan
  - Invest in test-beds during the Engineering and Manufacturing Development (EMD), and certainly before construction
  - Experiment with more than one technology as a contingency measure[17]

- Price Validation. Reduce risk by incentivizing the shipyard to help validate price by doing the following:
  - Presenting forward-pricing labor rates and overhead rates up to six years out, based on alternative outyear workload scenarios, and including justification.
  - Presenting fully documented shipyard cost estimates that meet U.S. and NATO standards.[18]

The results of the scoring session also support the fundamental consideration of selection of the contract type.[19] The total risk score applies here, which is the sum of the six Impact Factors:

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[17] See case studies on *Ford* Class carriers and Remote Minehunting System.
[18] NATO Research and Technology Organization (RTO) Technical Report “Methods and Models for Life Cycle Costing (Méthodes et modèles d'évaluation du coût de possession),” June 2007.
[19] Or more technically, types (plural) at the Contract Line Item Number (CLIN) level within the contract.

$$Total\ Risk = \mu_{w1} \cdot Score_{w1} + \mu_{w2} \cdot Score_{w2} + \cdots + \mu_{w6} \cdot Score_{w6}.$$

Risk decreases as a program progresses through the Adaptive Acquisition Framework[20] and into sustainment, as Figure 10 shows.

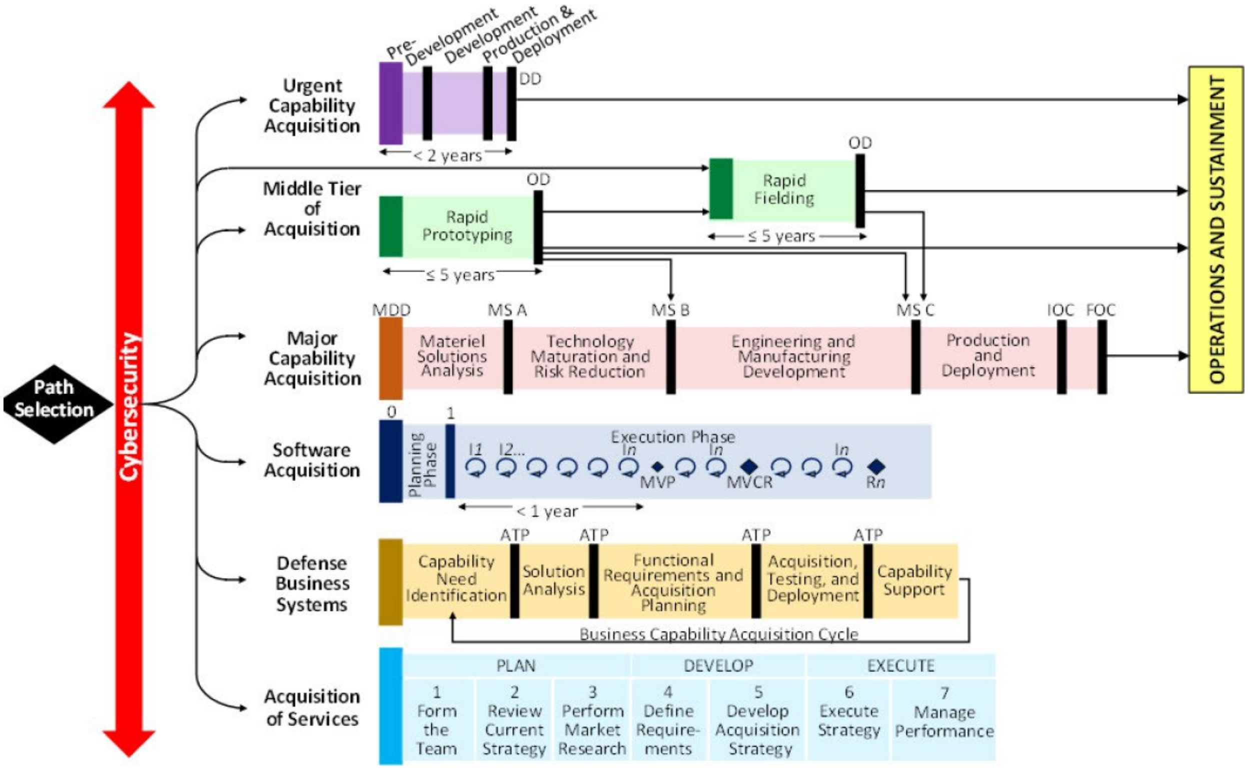

Figure 10: Adaptive Acquisition Framework

The diminution of risk is corroborated by cost growth studies in the U.S.[21] For U.S. contracts (and amongst NATO partners and Australia), cost-reimbursable is the common contract type early-on; that is, up until full-scale production of ships. However, this is not always the case (e.g., FFG-62 *Constellation* Class frigates). Further, in some cases, a cost-reimbursable was used for several ships in the class, and a block upgrade (LPD-17 *San Antonio* Class). To complicate matters, a cost-reimbursable contract should have been used, in retrospect, for contracts such as the USS *Kennedy*, the second ship in the CVN-78 *Ford* Class carrier project.

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[20] https://aaf.dau.edu/

[21] Weapon Systems Acquisition Reform Act (WSARA) and the Enhanced Scenario-Based Method (eSBM) for Cost Risk Analysis, Journal of Cost Analysis and Parametrics, 2012, Garvey, Braxton, Flynn, Lee.

Is there a numerical value that represents a tipping point in choosing between cost reimbursable and fixed-price incentive?

Based on a wide range of contracts and many ship acquisition programs, 1.5 seems a reasonable value. It represents a middle ground between low and high risk in the ratio scales of the scoring framework. That is, aggregate scores above 1.5 suggest the use of a cost-reimbursable contract while those below suggest the use of a fixed-price incentive. Contract ceilings (maximum expenditures) might be invoked in cases of high risk where the scores approach 1.7 or above.

The aggregate risk score influences the choice of the contract type, and the impact factors influence the application of incentives.

Importantly, however, this value is a rough-order-of-magnitude metric. Future research will focus on additional ex-post scoring of contracts and offer contract metrics for each of the phases of acquisition. In addition, subsequent research will present metrics probabilistically by conflating distributions of the scoring process.

As a corollary, the program should strive to drive down risk based on details of the scoring. For example, if Technology Maturity is greater than 1.7, then consider ways to mitigate the risk such as the use of test beds or an evolutionary approach to acquisition.

7.0 Summary

It must be cautioned that there is no “silver bullet” contracting solution guaranteed to produce optimal outcomes in all situations, even when restricted to the fairly uniform case of sole-source programs or programs in oligopolistic markets.

There is a common aphorism in the golf world, “You can’t win a Major on Thursday, but you can lose a Major on Thursday.”[22] The import is that those who shoot well in the opening round are often overtaken over the course of the remaining three rounds by better (and steadier) players only a few shots back, but that a poor opening round can doom a player, even the best, by digging too deep of a hole to climb out of. The analogy is that a poor choice of contract type, incentives, and methods of payment may doom a project to failure, but even an optimal choice will not guarantee success.

As an industry executive once opined during an ICEAA conference, “You can’t manage your way out of a bad deal.” To minimize this possibility, the contract risk-assessment model, summarized in Figure 11, increases the odds of a win-win outcome for government and industry through a sound, statistical selection of contract type and incentives.

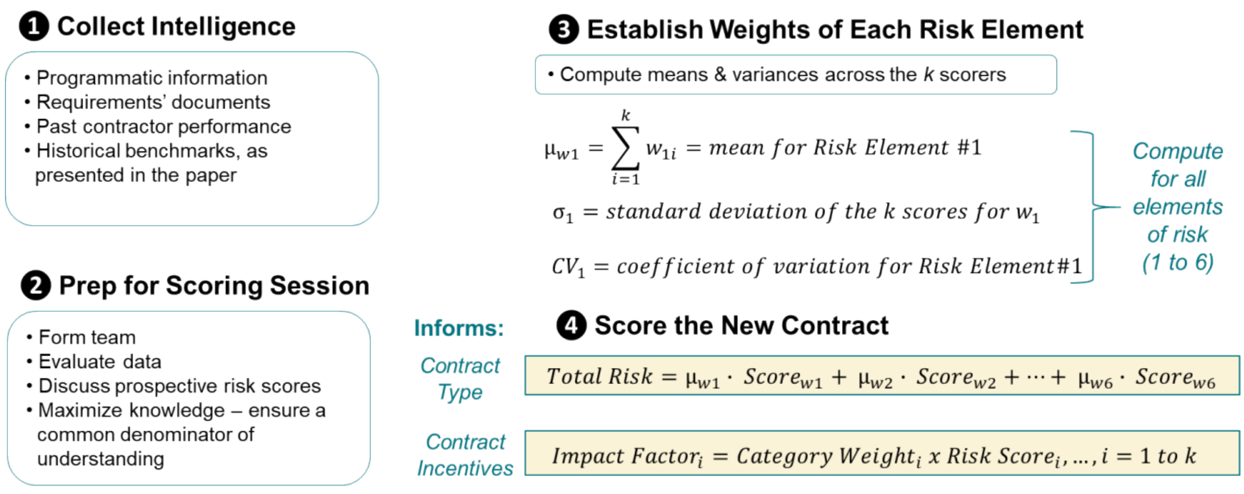


Figure 11: Contract Risk-Assessment Model

This research tilts the odds in the golfer’s favor (carrying the analogy one step further) and represents a significant advance in the application of sound, data-driven metrics to better illuminate contract risk and engender more informed pricing strategies.

[22] The annual quartet of Major tournaments comprises the Masters, the PGA Championship, the Open Championship (aka the British Open), and the U.S. Open. The opening round traditionally occurs on Thursday, with the remaining three rounds continuing throughout the weekend.

8.0 Next Steps

Despite the important advance that the research described in this paper represents, there is additional research and analysis to be accomplished in the interest of better contracting and acquisition decisions.

A more direct linkage between the risk scores and specific incentive contracting parameters (particularly, share line and ceiling price) is achievable if the risk scores could be translated into CGF and CV for the estimate itself. This has been done once before in the so-called BMDO Risk Model, cited in CEBoK Module 9 as the Historical Outputs-Based Model. An updated application for Ship programs would involve the melding of the CGFs in Appendix 2 and the Risk Scores in Appendix 4. One immediate challenge is the former, being derived from SARs, are at the program level, whereas the latter are at the contract level. The authors are considering this research for presentation at ICEAA 2024.

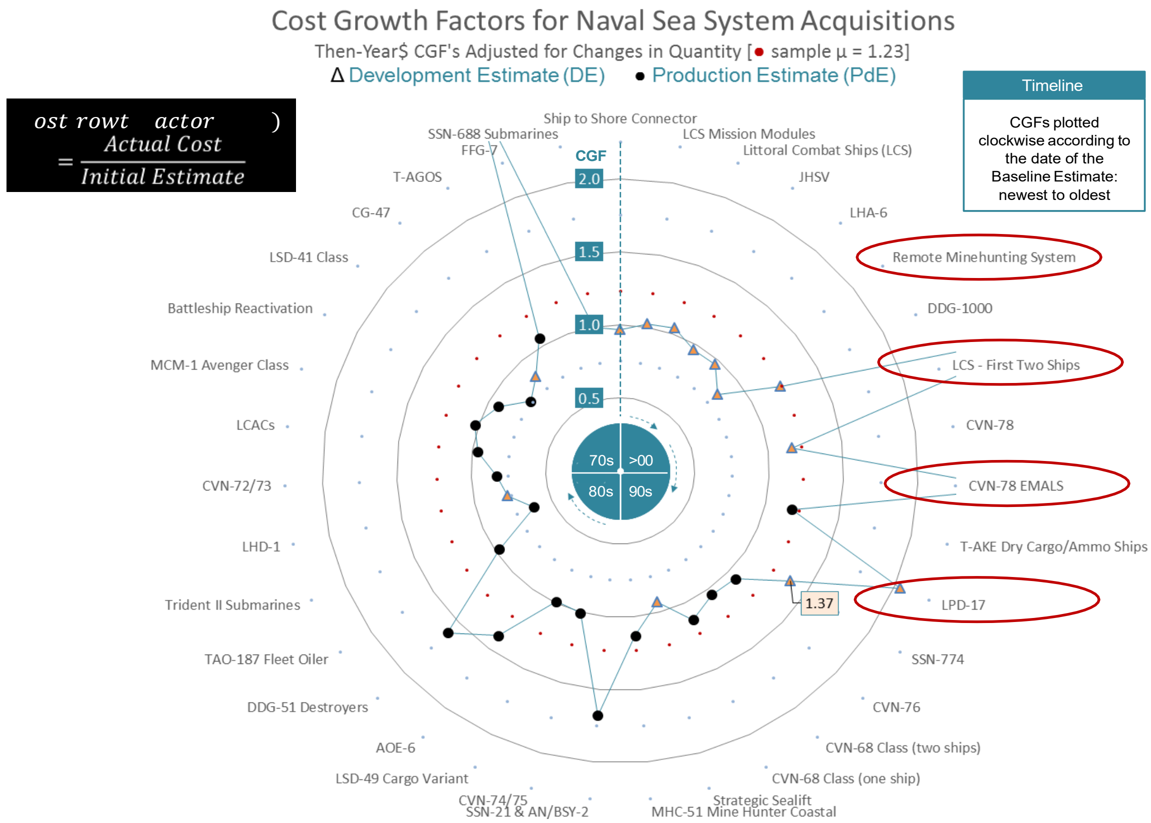
Regardless of whether a CGF and a CV are derived from a historical model as just described or are a result of the independent estimate for a new contract, the linkage between that stochastic cost estimate and proposed contract parameters can be achieved using the previously published Risk-adjusted Contract Price Methodology (RCPM). Rather than repeat that material here, an illustrative example of the unfortunate consequences of a mismatch between program risk and contract parameters is included in Appendix 5.

Appendix 1: Consolidation of the Defense Industrial Base[23]

Weapons Category	Total U.S. Contractors 1990	1998	2023	Current U.S.-Based Prime Contractors
Tactical Missiles	13	3	3	Boeing, Raytheon Technologies, Lockheed Martin
Fixed-Wing Aircraft	8	3	3	Boeing, Northrop Grumman, Lockheed Martin
Expendable Launch Vehicles	6	2	2	Boeing, Lockheed Martin
Satellites	8	5	4	Boeing, Lockheed Martin, Hughes, Northrop Grumman
Ships and Submarines	8	5	4	General Dynamics, Fincantieri Marinette, Huntington Ingalls, Austal
Tactical Wheeled Vehicles	6	4	3	AM General, Oshkosh, General Motors
Tracked Combat Vehicles	3	2	1	General Dynamics
Strategic Missiles	3	2	2	Boeing, Lockheed Martin
Torpedoes	3	2	2	Lockheed Martin, Raytheon Technologies
Rotary Wing Aircraft	4	3	3	Bell Textron, Lockheed Martin (Sikorsky), Boeing

[23] Source: Undersecretary of Defense (Acquisition and Sustainment).

Appendix 2: Cost Growth on U.S. Ship Contracts



Appendix 3: LPD-17 Scoring Details

Category	Weight	Rationale	Score

Stability of Requirements	15%	• Requirements changed slightly during design
		  ○ The original award fee was based on the total cost of the ship over its operational lifetime, or future maintenance costs in particular
		  ○ The incentive fee contract tied the fee to controlling construction costs; i.e., to delivering the ship in the face of cost growth
		• Otherwise, requirements were solid in terms of the overall mission to embark, transport, and land elements of a Marine landing force in an assault by helicopters, landing craft, and amphibious vehicles.
		  ○ Planned capacity and capability of the vessels remained virtually unchanged.
		  ○ Note that Block II is new.
			1.25

Market Forces	10%	• Two teams (duopoly) bid on the winner-take-all competition
		  ○ Avondale Team
		  ○ Ingalls Team
			1.50

Maturity of Technology	20%	• Regarded as "… the most highly technical and advanced amphibious ships ever built." • Significant advance in technology required, such as the enclosed mast.	1.75
Contractor Readiness	20%	• The DD&C contract was awarded to Avondale, a relatively "low tech" shipyard on the Gulf Coast that had not previously produced ships of the size and sophistication of LPD-17. • Intergraph, the yard's vendor for a 3D Computer Aided Design (CAD) of the entire ship, failed to meet expectations.	1.75
Price Validation	25%	• The Naval Sea Systems Command (NAVSEA) bought into the framing assumption of the shipyard that it would be at unit number four on the learning curve from the start. • Over-reliance on the yard's estimate without any independent validation or verification (until later).[24]	2.00
Schedule	10%	• Schedule was challenging given the advanced technology and use of untested design software.	1.75
Total			**1.71**

[24] Dr. Flynn assisted in the development of an Independent Cost Estimate (ICE) of the acquisition program after problems surfaced.

Appendix 4: Risk Scores for U.S. Naval Programs and Contracts

Project Parameters		Contract Risk Scores Based on Ratio Scales						
Ship Class and Contract	Contract Type	Stability of Requirements	Market Forces	Maturity of Technology	Contractor Readiness	Price Validation	Schedule Challenge	Aggregate Score
LPD-17 San Antonio Class (Amphibious Transport)								
Lead-Ship DD&C	CPAF → CPIF	1.25	1.50	1.75	1.75	2.00	1.75	**1.71**
LPD-18	CPIF	1.25	1.50	1.75	1.50	2.00	1.75	**1.66**
Steady-State LPD-22	FPIF	1.10	2.00	1.00	1.00	1.25	1.25	**1.20**
1st Block II: LPD-30	CPFF	1.25	2.00	1.25	1.25	1.25	1.25	**1.33**
2nd Block II: LPD-31	FPI	1.10	2.00	1.00	1.10	1.25	1.25	**1.22**
FFG-62 Constellation Class (Surface Combatant)								
Lead-Ship DD&C	FPI Firm Tgt	1.50	1.00	1.25	1.70	1.75	1.50	**1.50**
FFG-63	Option	1.25	1.00	1.10	1.30	1.75	1.25	**1.33**
Steady-State FFG-64	Option	1.10	1.00	1.00	1.20	1.75	1.20	**1.26**
DDG-1000 Zumwalt Class (Surface Combatant)								
DD(X) EMD	CPAF	2.00	1.50	1.75	1.75	1.50	1.50	**1.68**
System Design & Int'n	CPAF	1.75	1.50	1.75	1.75	1.50	1.50	**1.64**
Lead-Ship DD&C: BIW	CPAF	1.75	1.75	1.75	1.75	1.25	1.50	**1.60**
DD&C: Ingalls	CPAF	1.75	1.75	1.75	1.50	1.25	1.50	**1.55**
DDG-1001 Construction	FPI	1.50	1.75	1.50	1.25	1.25	1.25	**1.39**
DDG-1002 Construction	FPI	1.25	1.75	1.25	1.20	1.25	1.25	**1.29**
Advanced Gun System (AGS)								
Initial Design and Build	CPAF	1.75	1.75	1.75	1.75	1.50	1.75	**1.69**
AGS for DDG-1002	FPI	1.25	1.75	1.25	1.10	1.25	1.25	**1.27**
SSN-774 Virginia Class (Fast Attack Submarine)								
1st Boat in Block I	CPFF	1.40	1.75	1.35	1.40	1.25	1.60	**1.41**
1st Boat in Block II	FPIF	1.30	1.75	1.30	1.30	1.20	1.50	**1.34**
1st Boat in Block III	FPI Firm Tgt	1.25	1.75	1.25	1.35	1.10	1.50	**1.31**
1st Boat in Block IV	FPI Firm Tgt	1.25	1.75	1.15	1.25	1.00	1.40	**1.23**
1st Boat in Block V	FPIF	1.30	1.75	1.25	1.50	1.00	1.60	**1.33**
RMS Multi-Mission Vehicle (Mine Reconnaissance)								
Engineering Dev Model	CPFF	1.60	2.00	1.80	1.80	1.50	2.00	**1.74**
Initial Production (LRIP)								
Hardware	FFP	1.60	2.00	1.80	1.80	1.50	2.00	**1.74**
Engineering Svcs	CPFF	1.60	2.00	1.80	1.80	1.50	2.00	**1.74**
CVN-78 Ford Class (Nuclear Aircraft Carrier)								
"CVN-21" Constr Prep	CPIF, CPAF, CPFF	1.50	2.00	1.75	1.50	1.25	1.75	**1.56**
EMALS SDD	CPAF	1.50	2.00	2.00	2.00	1.75	1.75	**1.84**
Advanced Arresting	CPAF	1.50	2.00	1.75	1.75	1.75	1.75	**1.74**
Lead-Ship DD&C	CPIF, CPAF, CPFF	1.50	2.00	1.60	1.60	1.50	1.50	**1.59**
CVN-78 Prod'n	FFP	1.75	2.00	1.50	1.50	1.50	1.50	**1.59**
CVN-79 Constr Prep	CPFF/CPIF	1.30	2.00	1.50	1.50	1.50	1.60	**1.53**
CVN-79 DD&C	FPIF	1.20	2.00	1.40	1.30	1.60	1.40	**1.46**
CVN-79 & 80 Prod'n	FFP	1.25	2.00	1.40	1.30	1.30	1.40	**1.39**
T-AGS-66 Pathfinder Class (Oceanographic Survey)								
T-AGS-60	FFP	1.50	1.25	1.25	1.25	1.50	1.50	**1.38**
T-AGS-61 to T-AGS-65	FFP	1.20	2.00	1.25	1.00	1.50	1.25	**1.33**
T-AGS-66 and 67	FFP	1.20	2.00	1.00	1.00	1.50	1.25	**1.28**
LSD-41 Whidbey Island (Landing Ship Dock)								
LSD-41 DD&C	CPFF	1.50	1.25	1.50	1.60	1.50	1.50	**1.50**
LSD-42	CPAF → FPI	1.25	1.25	1.30	1.50	1.50	1.25	**1.37**
LSD-43	FPI	1.25	1.25	1.25	1.25	1.50	1.25	**1.31**
New Award (Avondale)								
LSD-44 to -48	FPI	1.20	1.00	1.25	1.75	1.80	1.50	**1.48**

Appendix 5: Calibration of Geometry for Incentive Contracts

An effective contract incentive structure relies on aligning Government and Contractor interests during execution, as illustrated in the bottom half of Figure 12. If the initial negotiations, wherein the parties' interest are naturally in opposition (as illustrated in the top half), fail to establish a reasonable Target Cost and other key parameters, then the program risks getting "stuck" in that Negotiation phase, with a continual parade of contract changes, instead of working together under the incentive mechanism in Execution.

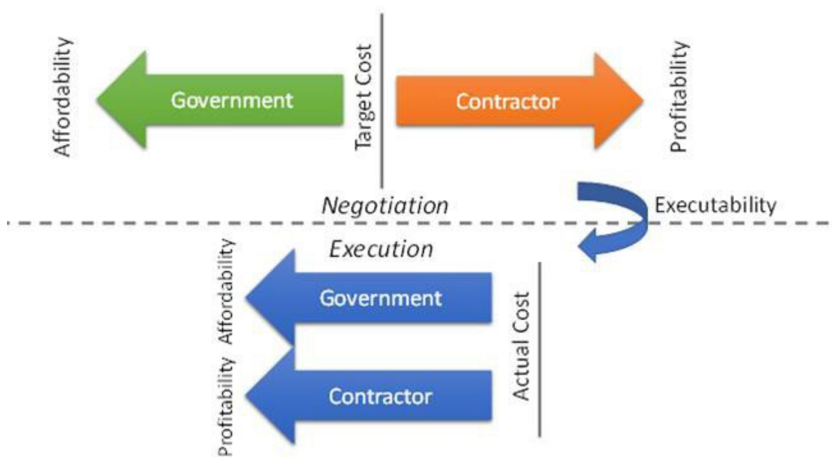


Figure 12: Contract Type as an Effective Contract Management Mechanism

This appendix provides a cautionary tale as to how *not* to set up an incentive arrangement and practical advice on how to avoid those potentially disastrous outcomes. In particular, it seeks to debunk the DPC default of a 50/50 shareline with 120% Ceiling Price for FPIF contracts.

The following metaphor is meant to illustrate the need for adequate mechanisms above target cost to encourage cost control while acknowledging that there is significant risk and uncertainty, especially for development and lead ship contracts. As shown in Figure 13, imagine a runaway truck barreling down the steep ROS curve from the favorable (underrun) outcomes on the left to the unfavorable (overrun) outcomes on the right. The illustration uses an FPI example with a target cost of $100M, target profit of 12%, ceiling price of 140%, and 80/20 and 70/30 sharelines over and under, respectively. (Graphics are generated using the Technomics Contract Incentive Impact Tool (CIIT).)

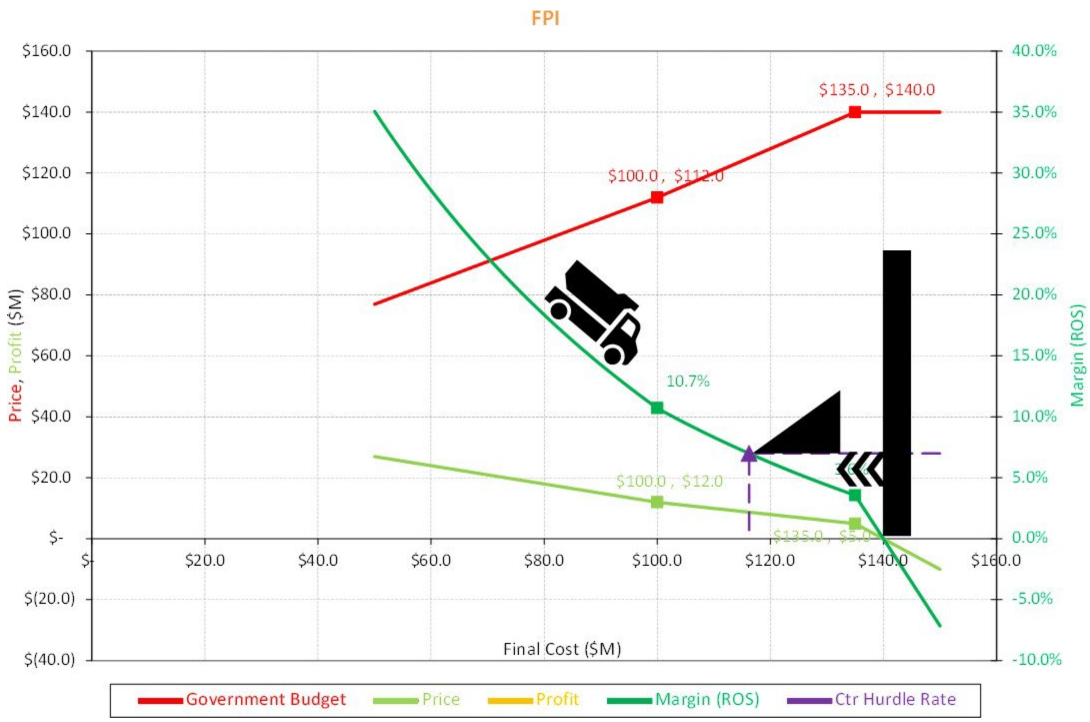


Figure 13: Runaway Truck with Safeguards

The first warning sign comes as the estimate at complete (EAC) passes target cost, forecasting an ROS of less than the 10.7% target. The truck starts applying its brakes, losing speed … and profit at 20 cents on the dollar of overrun. It's trying to stop short of the corporate hurdle rate of 7.0% ROS, which occurs at a final cost of $116.25M, or a 16.25% overrun, but the truck is too heavy and moving too fast. The driver steers off the motorway and onto a runaway truck ramp, which continues to slow the truck until the point of total assumption (PTA). In this case, that occurs at a final cost of $135M (35.0% overrun), and profit has eroded to $5M or an ROS of 3.57%, well below the hurdle rate but at least still positive. The truck has slowed significantly but is still in danger of crashing. The ground crew deploys caltrops (tire spikes) to shred the tires of the truck, and the truck lurches forward, now losing dollar for dollar of profit. It rumbles to a stop just short of the wall, the point at which profit disappears, a final cost of $140M (40% overrun).

By contrast, let's look at an FPI with only 10% target profit, 120% ceiling price, and 50/50 sharelines, as shown in Figure 14 below. This effectively makes the truck heavier and faster, the hill steeper and shorter, and the brakes less effective – a recipe for disaster! Barreling down the overrun hill, the truck is losing 50 cents on the dollar of profit and blows through the hurdle rate point at $104.3M (less than a 5% overrun). There is no time to deploy safeguards like a runaway ramp or caltrops. The driver desperately tries to apply the brakes, but they barely have an effect. Now the PTA and the point of zero profit are the same, at an actual cost of $120M (only a 20% overrun), and truck smashes into this wall and disintegrates into a fireball as the driver dives clear in a last-ditch attempt to avoid certain death.

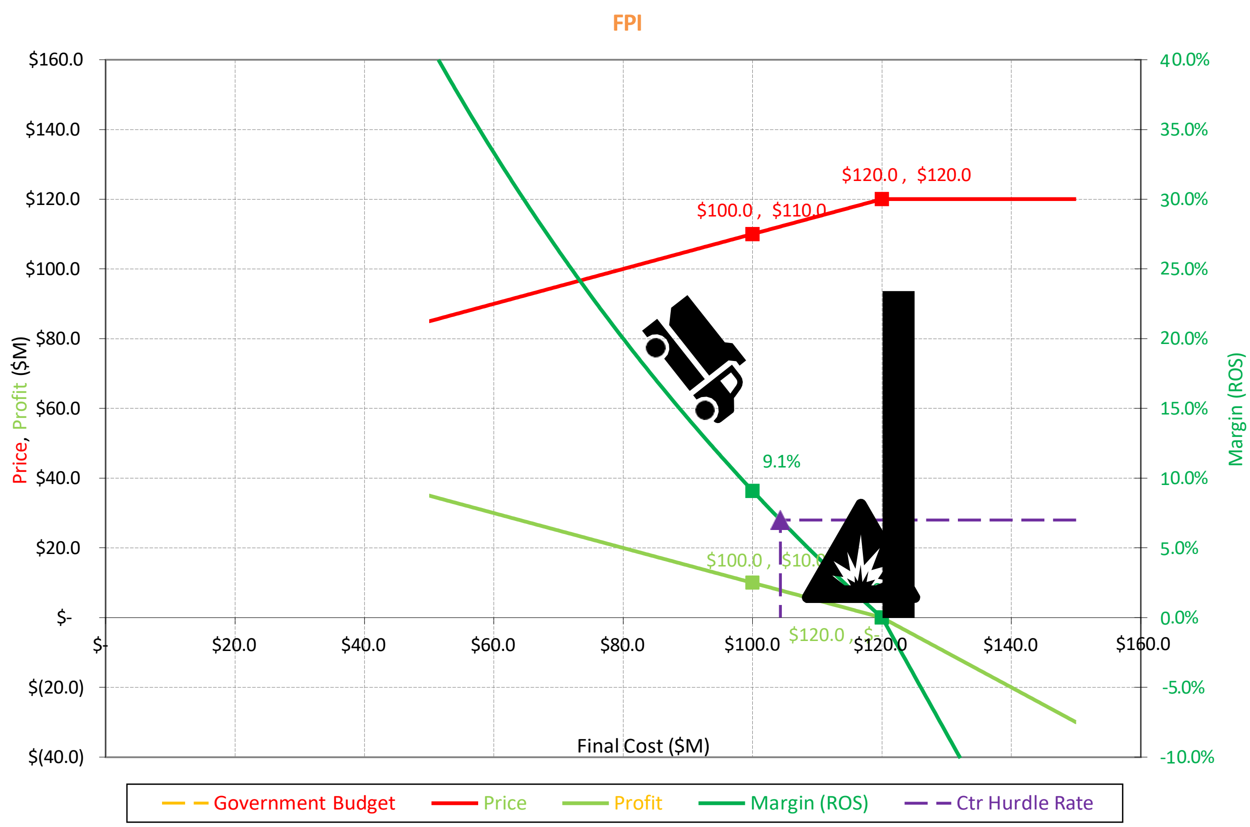


Figure 14: Runaway Truck without Safeguards

This narrative is a bit hyperbolic, but the scenario is still instructive. For a high-risk contract, steep sharelines (for the contractor), low target profit, and low ceiling price make for an unrealistically narrow range over which a cost control incentive is maintained for the contractor. If the government puts in place such punitive restrictions, it may prove to be self-defeating, as the contractor loses all motivation, and the project goes off the proverbial rails. The driver's bailing is symbolic of the project manager's literally quitting (or being fired) or mentally checking out. The government achieves a Pyrrhic victory, and any smugness at having negotiated such a parsimonious ceiling price evaporates upon the realization that both the delivery of the ship(s) and the health of the shipyard – a crucial component of the nation's Industrial Base – are at risk.

The 40% overrun in the previous scenario is not inevitable. Through a combination of prudent management and good fortune, we certainly hope to stop short of the first safeguard, or maybe even get the truck into reverse and end up to the left of target cost – a favorable underrun. Since the history of defense acquisition is littered with cost and schedule growth, however, it behooves us to put the safeguards in place.