ANS-LM-17-010

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Acquiring Technical Data with Renewable Real Options

8 November 2016

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Prepared for the Naval Postgraduate School, Monterey, CA 93943.

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
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Grant No. N00244-15-1-0012

FINAL TECHNICAL REPORT

Acquiring Technical Data with Renewable Real Options

by

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Abstract

This paper investigates the use of real options as a strategy to hedge risks in situations where the need for contract deliverables is uncertain over a long lifecycle. It focuses on the case of contracting for technical data to support competitive spares procurement, and proposes a data maintenance contract with renewable options to deliver technical data at a pre-negotiated price at the time of need and the required level of data rights. A business case analysis tool is developed using dynamic programming to calculate the value of the technical data options to the government. This tool is applied in an example using available cost data to support a series of annual decisions on whether to continue the option, and to determine the optimal timing to exercise the option to rent or buy the technical data based on the expected cost avoidance to the government. This options-based approach helps the government avoid the costly acquisition of technical data that may never be used while ensuring data are available when a need arises. Industry also benefits from the data maintenance contract as a business opportunity that provides more accurate data for system support and better insight into government uses of the data.

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Acknowledgements

This material is based upon work supported by the Naval Postgraduate School Acquisition Research Program under Grant No. N00244-15-1-0012, awarded by Naval Supply Systems Command Fleet Logistics Center San Diego (NAVSUP FLCSD). The views expressed in written materials or publications, and/or made by speakers, moderators, and presenters, do not necessarily reflect the official policies of NPS nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government.

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About the Author

Dr. Michael McGrath—holds a B.S. in Space Science and Applied Physics and an M.S. in Aerospace Engineering from Catholic University, and a doctorate in Operations Research from George Washington University. As a former Vice President at ANSER, he led business operations in Systems and Operations Analysis. He previously served as Deputy Assistant Secretary of the Navy for Research, Development, Test and Evaluation, and is a strong proponent for improvements in technology transition, modeling and simulation, and test and evaluation. His research interests are in cybersecurity for manufacturing and procurement and use of digital technical data.

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Introduction

Acquisition program managers are expected to acquire technical data needed for life cycle sustainment functions such as maintenance or competitive spare parts procurement, but this expectation is more complicated than it seems (Department of Defense, 2015). The needs and timing for competitive spare parts procurement are uncertain, and changes in system configuration or sustainment strategy can alter the need for technical data. Additionally, price negotiation for the technical data package (TDP) often occurs in a sole source environment, with conflicting assertions by the contractor and government over rights in data, an issue that is compounded by inadequate business case evaluations of the value of the data to the government (DoD, 1993). In some instances, prices in excess of $1 billion have been quoted for the acquisition of TDPs (Government Accountability Office, 2011). Consequently, TDPs that are needed are often not acquired, TDPs that are acquired are often not properly priced, and TDPs that are delivered may never be used. Program managers need better ways to hedge uncertainty in technical data needs and better business case analysis tools for the procurement of TDPs.

This research investigates a new method for acquiring technical data with flexible options to be exercised at the time of need during the product life cycle. The option would allow the government the right, but not the obligation, to rent or purchase the technical data and technical data deliverables at the time the data are needed. Purchasing an option preserves the opportunity to acquire technical data deliverables at a set price while hedging the risk that the technical data ultimately may not be needed. Because the data are not acquired until the time of need, this helps to ensure that the associated data rights are acquired at the appropriate level for the intended technical data use. This allows program managers the ability to continuously reassess needs and mitigate changes in supply chain, system configuration, or sustainment strategy.

To calculate the value of an option to the government for the purchase of technical data rights and deliverables, we use real options theory, which accounts for the costs or savings associated with various alternative outcomes. Real options theory originated from the valuation of options in the financial market. Instead of valuing the option to purchase a stock, however, real options theory extends this valuation to the purchase of “real” things such as technical data packages, which we explore in detail. We use dynamic programming to value the real option, and package the valuation algorithm in a user-friendly Excel-based business case analysis tool that is freely available. We present a proposed business model for how to use this business case analysis tool in a real-world scenario.

Although there are many government needs for technical data (engineering investigations, depot maintenance, spares procurement, etc.) we limit our focus in this research to TDPs and associated data rights used in competitive procurement of spares and repair parts. A complete TDP will cover all the parts in a system or subsystem. Although spares (repairable items) and repair parts (consumable items) are managed differently in the DoD supply system, there is no difference from the standpoint of TDP data deliverables needed to support competitive procurement. So, for simplicity, we will use the term spare parts to include both categories. To illustrate the decision support tool proposed for the new acquisition approach, we use a scenario involving the data deliverables and data rights needed for competitive procurement of a single part numbered item.

Current Acquisition Policy and Practice

Department of Defense (DoD) acquisition policy requires the acquisition program manager to consider procuring technical data and associated data rights during acquisition. Implicitly underlying this policy is an expectation that the acquisition cost of technical data will be more than offset by the downstream benefits of competition and other benefits of DoD use of the data. DoD Instruction 5000.02 (2015) requires that “Program management must establish and maintain an IP [Intellectual Property] Strategy to identify and manage the full spectrum of IP and related issues (e.g., technical data and computer software deliverables, patented technologies, and appropriate license rights) from the inception of a program and throughout the life cycle”. This requirement was strongly re-emphasized in DoD’s Better Buying Power 2.0 (BBP 2.0) initiative as a means to ensure that DoD is positioned for competitive sourcing of materials needed for sustainment and upgrades to the system (Kendall, 2012). As a result of BBP 2.0, DoD published a Data Rights brochure, updated DoD Instruction 5010.12M on Procedures for the Acquisition and Management of Technical Data, and developed an Intellectual Property Strategy Guidance brochure to support data rights planning. Army, Navy and Air Force documents provide further guidance on the acquisition of the data deliverables that comprise a TDP. Technical data is a significant area of emphasis in DoD acquisition policy; Federal Acquisition Regulations provide standard contract requirements for acquisition of technical data and associated IP rights, MIL STD 31000a prescribes the content of TDPs and TDP data management products, and the DoD acquisition workforce is trained in assessing technical data needs, conducting business case analyses on technical data acquisition strategies, and contracting for data and data rights.

In practice, however, it is difficult to determine life cycle data needs, evaluate the business case, negotiate and contract for priced data rights and deliverables, validate deliverables, maintain technical data, and make the data accessible for use over an extended period. Additionally, industry is reluctant to release technical data that may be used by potential competitors. There may also be circumstances, such as contractor maintenance of the system under a Performance Based Logistics (PBL) arrangement, where the government may not need the data during a specified period, but may need the data later to maintain a competitive market. Given the uncertainty of needs and the difficulty and expense of procurement, technical data are often deferred or put in a contract option that is never exercised. The Government Accountability Office (GAO) has published several reports critiquing the Department's handling of technical data acquisition. In 2004, GAO reported that "program managers often opt to spend limited acquisition dollars on increased weapon system capability rather than on acquiring rights to the technical data – thus limiting their flexibility to perform maintenance work in house or to support alternative source development should contractual arrangements fail". In 2010, GAO reported "For 27 of the 47 noncompetitive DoD contracts we reviewed, the government was unable to compete requirements due to a lack of access to proprietary technical data". More recently, GAO (2011) reported that, although DoD policies have been updated to require determination of data needs, business case analysis and inclusion of technical data and data rights in the acquisition strategy, these policies are sparsely implemented in the acquisition programs they reviewed. The disconnect between technical data acquisition policy and practice has been a longstanding issue in DoD.

In section 4, we propose a new acquisition approach designed to address these pragmatic difficulties by creating and preserving competitively priced options for deferred delivery of, or access to, technical data at the time of need throughout the life cycle. This approach is motivated not only by the need to reconcile policy and practice, but also by the opportunity to take advantage of technology trends affecting technical data.

Technology Trends Affecting Technical Data

Two important industry trends are changing DoD practices for acquiring and using TDPs: 3-dimensional (3D) digital product models and product lifecycle management (PLM) systems.

3D digital product models have revolutionized industry engineering practices, and are now affecting DoD practices. When DoD policies and standards for TDPs were originally developed, hard copy 2D engineering drawings produced by draftsmen were the norm. These drawings required interpretation by skilled machinists to produce a part. The broad adoption in the 1980s of computer aided design (CAD), computer aided engineering (CAE), and computer aided manufacturing (CAM) systems shifted this paradigm. Today, the aerospace and defense industries use CAD/CAE systems to generate engineering data in digital form, often called the “digital thread” or “digital tapestry” that drives modeling, analysis and automated processes throughout the manufacturing enterprise (Model Based Enterprise, 2016). DoD is gradually equipping itself to acquire and use 3D digital data in engineering, maintenance and supply applications. The advantages of a 3D TDP for spares procurement were demonstrated in a recent Manufacturing Technology program (U.S. Army Armament Research, Development and Engineering Center, 2009). Faced with diminishing sources for M2 .50 caliber machine gun parts, an Army engineering center entered the old 2D drawings into a CAD system, generated a 3D TDP, and prototyped the part to capture the manufacturing recipe. When the validated 3D TDP and manufacturing process data files were released, bids were received from new suppliers who said they would not have bid without the digital files. The parts were ultimately delivered with a 70% savings in manufacturing run time and a 45% savings in cost compared to prior procurements. The conclusion is that the value to the government of a TDP used for spares procurement increases when the TDP is available in a 3D format. Other government users of TDPs in engineering and maintenance organizations have similarly concluded that 3D TDPs add considerable value. Recognizing the value of 3D TDPs, DoD has issued a new standard practice for acquiring either 2D or 3D

TDPs (DoD, 2013). For the technical data acquisition approach proposed in this research, we assume the government will prefer delivery of 3D TDPs.

PLM systems are a more recent development in industry, but have grown rapidly, reaching $40 billion in global sales in 2014. An article in PR Newswire recognized this rapid growth, noting that “Aerospace and defense was the largest end-use segment of the PLM market in 2014. This segment has a significantly long product development cycle and in order to manage this, the companies in this sector started adopting PLM solutions in wide manner” (Wood, 2015). The primary function of a PLM system is to manage product information of all types used in engineering, manufacturing, product support and business processes throughout the life cycle. Product information starting in the conceptual phase is developed in a distributed collaborative environment, linked, configuration-managed and made accessible to downstream users for re-use without duplicating the data or allowing it to get out of synch. The value to industry stems from the ability of PLM systems to reduce time and errors associated with locating complex data sets and reconciling version control issues. Government organizations see potential value in using PLM systems to archive and manage technical data delivered to the government. Naval Air Systems Command, for example, is reviewing the capabilities of systems offered by major PLM vendors with a view toward procuring such a system (Owens & Gordon, 2014). Some PLM systems enable trusted partners to share access to a PLM database and associated CAD systems, to export data sets from one PLM system for ingestion into another PLM system, or to create digital files (e.g., a 3D TDP) for transmission to users who have no PLM access (Doyle & Grossman, 2014). Such systems typically include strong digital rights management features that are suitable for protecting intellectual property in both commercial and government uses. The technical data acquisition approach in the next section assumes that in the future, contractor and government organizations will use PLM systems to manage technical data for speed and accuracy in the generation of a bill of materials, 2D drawings and 3D product models, supporting engineering analysis data, manufacturing process and tooling data, and numerous other uses.

A New Acquisition Strategy for Technical Data

As described by GAO (2011), the current acquisition approach has four phases:

1. Requirements, strategies, and plans phase – the government determines needs for technical data and data rights, and includes those requirements in the acquisition strategy and plan.
2. Contracting phase – the government specifies data requirements in the solicitation, evaluates competitive contractor proposals, negotiates, and awards a contract.
3. Contract performance and delivery phase – the contractor develops and delivers (or provides access to) technical data per the contract. Delivery may be deferred at the government's option for up to three years after the end of the contract (Code of Federal Regulations, 2016). Ultimately, the government accepts delivery of the data into a government storage and distribution system.
4. Post-performance and sustainment phase – the government uses the technical data in engineering, maintenance, supply support, and other life cycle functions.

The proposed new method uses the same four phases, but adds flexibility by using a subscription to the contractor PLM system for online access and options for deliverables to hedge risks and uncertainties in life cycle needs for technical data. Key differences are:

- Needs determination is essentially the same in Phase 1, but a new business case analysis tool (described in Section 5 below) is used in developing an options-based acquisition strategy. This tool considers the value to the government of having the option, at any point in the life cycle, to access technical data maintained by the contractor, rent TDPs for one-time use, or deliver TDPs to a government system.
- In Phase 2, the solicitation requires online access through a subscription to the contractor's PLM system (with appropriate data rights) during the contract period, and competitively priced options for delivery or one-time use (rental) of TDPs that may be exercised up to three years after the end of the contract using a standard DoD contract clause (CFR, 2016).
- In Phase 3, the government has the option to accept delivery of data, but relies primarily on access to the contractor PLM system. For data deliverables this is similar to the deferred ordering clause in DoD 5010.12-M,

which "ensures the availability of the raw data while avoiding the cost of buying the data, if the need never arises". The proposed framework differs in that all data deliverables are priced during Phases 2 and 3 at the appropriate level of rights. In contrast, the deferred ordering clause pertains only to items developed at government expense, in which case "the contractor is compensated only for the cost of converting the technical data or software into the required format and for reproduction and delivery". Also in Phase 3, the government plans and negotiates a sole source follow-on data maintenance contract for award before the base contract data options expire. This sole source negotiation is bounded by the fact that the government can exercise the prior competitively priced option for delivery of all the data if the proposed price of follow-on data maintenance is too high. The data maintenance contract also includes a subscription to the contractor PLM system that may be renewed as needed throughout the life cycle.

- Finally, in Phase 4 the government meets life cycle needs either by using data already delivered into a government system or by making case by case decisions at the time of need on whether to exercise an option for data delivery or one-time use (rental), with pricing based on the level of data rights needed. Figure 1 illustrates the data flow between contractor and government systems in Phases 3 and 4.

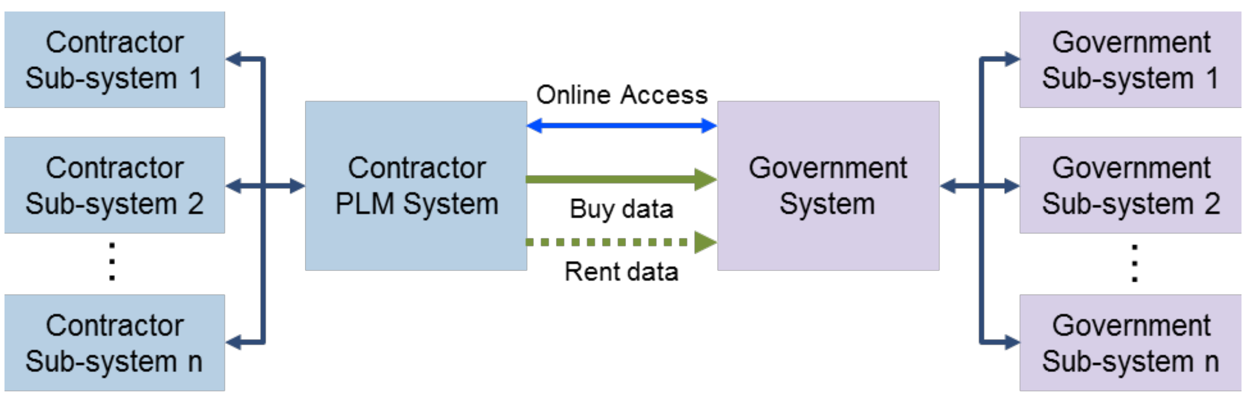

Figure 1. Modes of Data Flow between Contractor and Government Systems

The major effect of this new acquisition approach is that it allows the government to acquire only the technical data needed, with the data rights needed, at the time of need rather than acquiring all the data during acquisition with the highest level of data rights. In current practice, data not procured during acquisition may later have to be priced and procured in a sole source environment. The new approach preserves option prices that are competitively priced in the acquisition phase.

An excellent example of using competition for leverage on pricing is the Request for Proposals (RFP) for the Joint Logistics Tactical Vehicle Family of Vehicles (JLTV FOV) (U.S. Army Contracting Command, 2014). The RFP required that the contractor develop and maintain the TDP for the life of the contract, that the government have the option for purchase and delivery of the TDP at a firm fixed price, and that the contractor warrant the correctness of the TDP. The government required that the 3D product model be the design master record, and that delivery under the contract option use a government PLM system: “The Contractor shall perform all work under this contract using the Government Windchill PDMLink, beginning with the date the Government exercises the TDP Option and shall provide models and CAD files which successfully pass the quality checks and Windchill PDMLink release process defined in these modeling standards”.

To incentivize delivery of a complete TDP, the RFP included a novel provision that gave the offerors credit for a TDP Adjustment in the Total Evaluated Cost/Price factor in source selection (U.S. Army Contracting Command, 2014). The TDP Adjustment was based on a government estimate of $511 million in expected life cycle savings if the TDP supported future full and open competitive acquisitions. Credit was given for the difference between the offeror’s TDP price and government savings estimate, adjusted by completeness of the offered TDP and data rights. The three offerors responding to the RFP were incentivized to get maximum credit by offering TDPs with no restrictions on use for competitive re-procurement, thereby allowing the government to avoid the cost of reverse engineering and qualification testing for secondary sources.

According to current government users of technical data, past practice in exercising TDP purchase options has often encountered problems in the timeliness of delivery, completeness, and accuracy of technical data deliverables. Contractor and government PLM systems will be helpful in avoiding past problems in delivery times, review of data rights markings, configuration accuracy and completeness of TDPs. A continued contractual relationship during the sustainment phase would allow the government to enforce contract requirements more easily. In the new acquisition method, provisions of the data maintenance contract could include requirements for timeliness of delivery, accuracy, and completeness of the TDP for use in competitive re-procurements, and specified formats for deliverables suitable for government repositories or PLM systems.

From the contractor point of view, the subscription to the contractor PLM system presents a new business opportunity over the life cycle. Making accurate, up-to-date data available for government purposes can avoid problems for the contractor as well as the government. Perhaps the greatest benefit, however, is the ability to avoid potential delays in production decisions by agreeing on options rather than relying on the government to find full funding for technical data acquisition to meet acquisition milestone decision requirements.

A Decision Framework Based on Real Options Theory

The options-based method for acquiring technical data requires government decisions on whether to contract for options, whether to extend options by renewing the data maintenance contract, and whether/when to exercise options to rent or buy the data at the appropriate level of data rights. The nature and timing of a government need for technical data is uncertain. Therefore, we use a real options theory approach to calculate the expected value of the option to acquire the TDP and determine the optimal time to exercise this option.

Real Options Theory

Real options theory grows out of the valuation of options in the financial market. There, the purchase of an option allows the purchaser the right, but not the obligation, to buy or sell a stock at a fixed price. The decision of whether to purchase the option is based on the calculation of the option's value relative to the cost of the option (Goudarzi & Sandborn, 2015). As an example, imagine a stock that is currently trading at $80, where the cost of an option is $15 for a one-year option to purchase the stock at the exercise price of $70. If you purchase the option, and exercise it on the same day, the payoff would be $10 for the stock, but the cost of the option is higher than this payoff, meaning you would end up losing $5. If you waited, however, and the value of the stock increased to $100, you could then exercise the option at the $70 exercise price, and will make $15 ($100 current trading value - $70 exercise price - $15 option) (Leslie & Michaels, 1997).

Real options theory extends this logic to real assets, such as factories, real estate, mines, and intellectual property (Sick & Gamba, 2005). In real options terms for technical data, the purchase of an option allows the purchaser the right, but not the obligation, to acquire the TDP and deliverables at a fixed price. In addition to addressing the question of "what should I pay to buy the option?" real options theory also assists in determining when the option should be exercised (Goudarzi & Sandborn, 2015). For the case of technical data, we use real options theory to account for the uncertainty in need associated with spare parts as well as the variability in costs of acquiring the parts. Calculating the value of the option at various stages in the program life cycle provides the program manager the information necessary to purchase only the technical data that is needed at the time that it is needed, and at the appropriate level of rights, avoiding the costly acquisition of technical data that may never be used, or the acquisition of technical data at a level of rights that is not necessary.

The traditional method to value stock options is the Black-Scholes model, proposed by Black & Scholes in 1973. Variations of the Black-Scholes model are still widely used, but the basic assumptions of the model generally do not hold for the valuation of real options. The Black-Scholes model makes assumptions about constant volatility in price, normal distribution of returns and lognormal distribution of underlying asset value—assumptions that do not fit many real option scenarios. More importantly, the Black-Scholes model was developed to value a European-style option, which is an option that must be exercised at a fixed point in time. Real options, on the other hand, are usually better conceptualized as American-style options, which can be exercised at any point in time over the life of the option (Gilbert, 2004).

To calculate the value of our real options for the purchase of technical data and data rights, we structure the problem as an American-style option that can be exercised at the time of need, but must be renewed on a scheduled basis. We calculate the value of the option to the government based on the year by year probability of need (Bayesian prior probability) and an evaluation of expected cost avoidance. Essentially, we are valuing the benefit of avoiding the expenses of working around the lack of technical data that would be necessary had the TDP not been available. For example, lack of technical data might necessitate sole source procurement of a spare part from the original supplier. If there is a 25% savings associated with competitive procurement of the part, this savings would be a source of cost avoidance to the government.

Decision Tree for Technical Data Options

In Phases 3 and 4 of our technical data acquisition method, there are two recurring decisions to be evaluated. The first considers whether to pay to keep the option open or allow it to lapse. The second considers whether to exercise the option (buy or rent the technical data) at the time a need occurs. Both decisions are based on the expected net cost avoidance associated with various government uses, summed across the remaining years of the life cycle. We can represent this as a decision tree, as shown in Figure 2, that decides each year (labeled stage s) whether to renew the data maintenance contract and data delivery options, and then decides during the year whether to exercise an option based on operational needs.

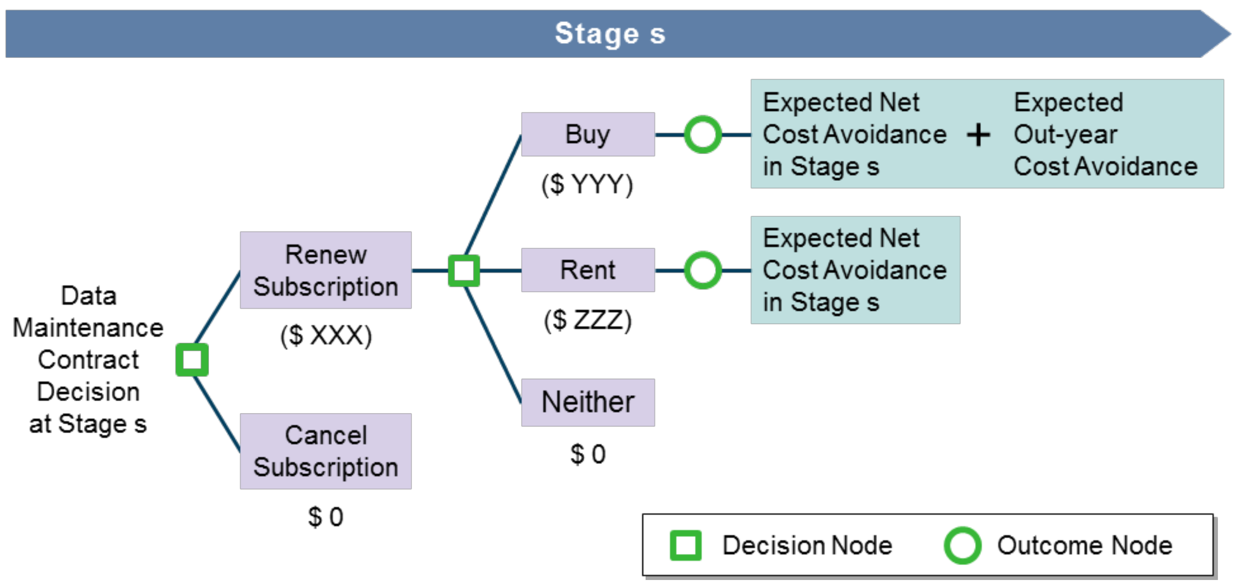

Figure 2. Iterative Decision Tree

Decision trees are evaluated by working backward, from right to left. For simplicity, assume that this subscription only contains one technical data deliverable and consider just decisions that occur during one year (stage s). For the buy option (top branch of the decision tree), if the government buys the technical data, there is a cost avoidance in the current stage (expected net cost avoidance in stage s), and in all subsequent stages in the future (expected out-year cost avoidance), since the technical data are now available in a government system for future use. For the rent option, because the technical data are rented for a limited time, the cost avoidance accrues to the government only during the rental period (expected net cost avoidance in stage s). If the technical data are neither bought nor rented during stage s, there is no cost avoidance. The value of renewing the subscription, then, depends on which decision is chosen (buy, rent, neither) and on the inherent value of online access to the contractor system for data that has not yet been delivered.

Since we are working backward, and this is a multi-stage (i.e., multi-year) problem, we set stage s to be s=N-1 where N is the last year of the life cycle, and work backward from there. If a need occurs with only one year of life remaining, only one year of cost avoidance is possible. Assuming it is less expensive to rent the data than to buy it, the decision would be to rent the data or to do without, whichever generates the larger expected net cost avoidance. If we know the probability of need for spare parts in the last year of the life cycle, the difference in cost between meeting that need with and without delivered technical data, and the cost of renting the technical data, we can compute the expected net cost avoidance and choose the optimal path for that year.

In similar fashion we can back up another year (s=N-2), and evaluate expected net cost avoidance for each branch in the decision tree. We compute the current year expected cost avoidance for the buy and rent options, and for the buy option also add in the out-year cost avoidance calculated in the previous step. We continue to work backward to the current year, always choosing the decision for each year that maximizes cost avoidance, and recognizing that once the "buy" decision is chosen, all remaining out-years benefit from the availability of technical data. This results in an optimal path through the many branches of the multi-stage decision tree shown in Figure 3. The example scenario discussed below will illustrate one such optimal path.

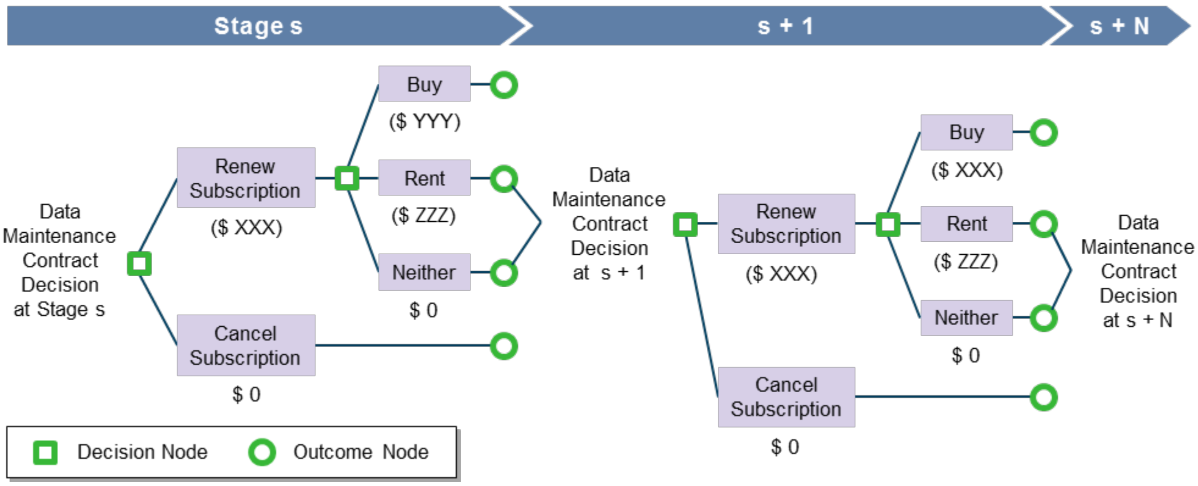

Figure 3. Multi-stage Decision Tree

Formulation as a Dynamic Programming Problem

We recognize this multi-stage decision problem as belonging to the class of dynamic programming problems first addressed in the 1950s (Bellman, 1954). To find the series of decisions that will maximize cost avoidance, we define the following variables:

$$\boldsymbol{stage\ s} = [0,1,2 \ldots \boldsymbol{N}], where\ \boldsymbol{N}\ is\ the\ last\ year\ of\ the\ life\ cycle$$
$$\boldsymbol{decision\ variable\ x_j} = [Buy, Rent, Neither]\ for\ \boldsymbol{j} = [1,2,3]$$
$$\boldsymbol{C_{sx_j}} = Expected\ net\ cost\ avoidance\ in\ stage\ \boldsymbol{s}$$
$$if\ \boldsymbol{x_j}\ is\ chosen\ (net\ of\ option\ cost)$$
$$\boldsymbol{C_s^*} = \max[j]\, C_{sx_j}$$
$$\boldsymbol{CG_{sx_j}} = Expected\ gross\ cost\ avoidance\ in\ stage\ \boldsymbol{s}\ if\ \boldsymbol{x_j}\ is\ chosen$$
$$\boldsymbol{f(s, x_j)} = total\ cost\ avoidance\ of\ best\ policy\ (sequence\ of\ choices)$$
$$for\ the\ remaining\ stages\ given\ we\ are\ in\ stage\ \boldsymbol{s}\ and\ choose\ \boldsymbol{x_j}$$

We maximize total cost avoidance by starting at stage N-1 and working backward, choosing $\boldsymbol{x_j}$ in stage $\boldsymbol{s}$ that maximizes:

$$\boldsymbol{f(s, x_j)} = C_s^* + (1 - \delta_s) \sum_{i=s+1}^{N} C_i^* + \delta_s \sum_{i=s+1}^{N} CG_{ix_1}$$
$$where\ \boldsymbol{\delta_s} = 1\ if\ \boldsymbol{C_s^*} = \boldsymbol{C_{sx_1}}\ and\ \boldsymbol{\delta_s} = 0\ otherwise$$
$$since\ "buy"\ avoids\ subsequent\ gross\ costs$$

This can be visualized as the decision tree shown in Figure 4.

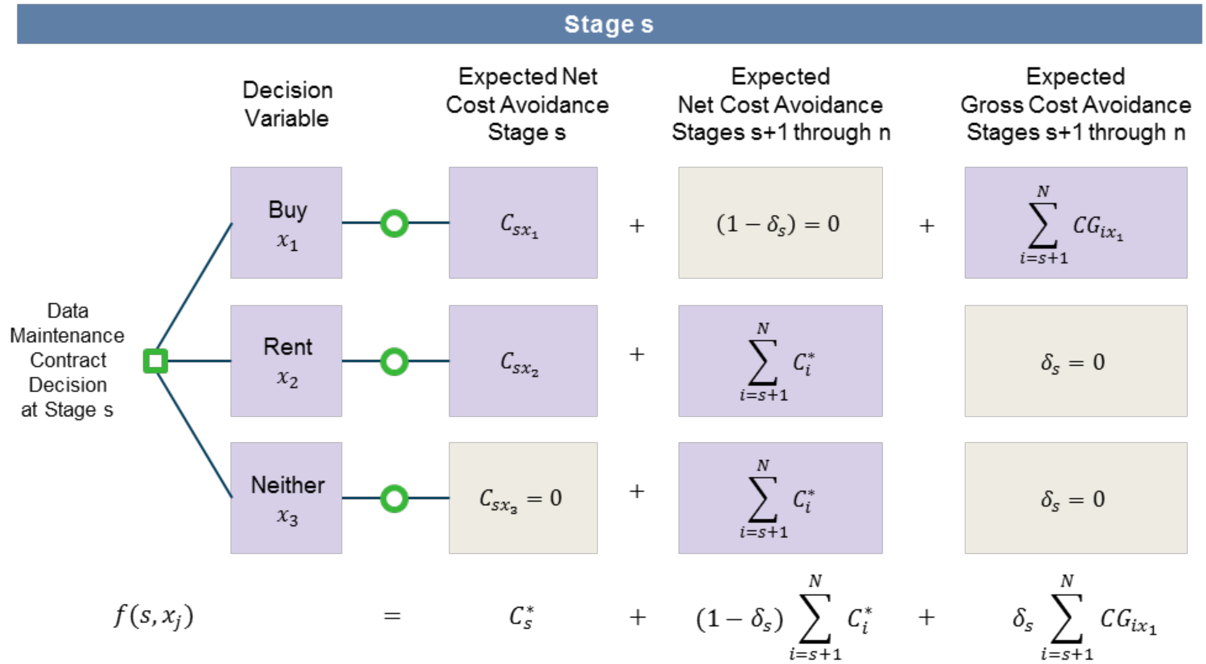

Figure 4. Decision Tree Showing Dynamic Programming Equation to Calculate Value of TDP Option

For ease of computation, we developed a recursive algorithm to evaluate ***f(s,x$_j$)*** for each year of the life cycle, starting from the final year:

$$Let\ \boldsymbol{OY}_{sx_1} = outyear\ gross\ savings\ if\ x_1\ is\ chosen\ in\ period\ s$$

$$\boldsymbol{OY}_{sx_1} = \sum_{i=s+1}^{N} CG_{ix_1}$$

$$Then\ \boldsymbol{f}(\boldsymbol{s},\boldsymbol{x_j}) = C_s^* + (1-\delta_s)\sum_{i=s+1}^{N} C_i^* + \delta_s OY_{sx_1}$$

Starting at ***s=N-1*** and working backward,

$$\boldsymbol{f}(\boldsymbol{N-1},\boldsymbol{x_j}) = C_{N-1}^* + (1-\delta_{N-1})C_N^* + \delta_{N-1}OY_{(N-1)x_1}$$

$$\boldsymbol{f}(\boldsymbol{N-2},\boldsymbol{x_j}) = C_{N-2}^* + f(N-1,x_j)$$

$$\ldots$$

$$\boldsymbol{f}(\boldsymbol{s},\boldsymbol{x_j}) = C_s^* + f(N-s+1,x_j) \quad \text{(This is a recursive algorithm)}$$

This algorithm has been implemented in an Excel spreadsheet model that is freely available[1]. The required inputs for this model are: the year-by-year probability of being in a buy position for spare parts, the forecasted buy quantity of parts to be procured, projected cost resolution data if TDP is not available, the purchase price of the TDP, the rental price of the TDP, the sole source price of a single spare part unit, the life cycle duration for which spare parts are required, and the discount rate, if any, to be applied for net present value calculations.

With this business case analysis tool, for any given spare parts acquisition scenario, the total cost avoidance can be calculated to determine the initial benefit and support the decision to include the data maintenance and data delivery option line items during initial acquisition. The decision of whether to continue the data maintenance and delivery options in follow-on contracts can be evaluated with the same tool. Finally, the tool can be used as needs arise during the life cycle to decide whether to buy or rent the technical data or to meet the need without delivery of technical data.

Example scenario

The following example shows how the calculations might apply to decisions on a TDP to support spare parts procurement. The scenario assumes that:

- The probability of being in a spare parts buy position (p(spares)) in any given year is as shown in Table 1[2]. When spare parts are procured, the buy quantity is always a lot of 100.
- The system life cycle is 20 stages, or years. A contractor PBL program is in force for the first three years of operation (to illustrate how options-based acquisition of data could complement other acquisition practices).
- The cost of the subscription is zero. In practice, the cost of the subscription would be significant and would be amortized across multiple data

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[1] Full text available at: http://anser.org/docs/reports/Acquiring_Technical_Data_with_Renewable_Real_Options.pdf, spreadsheet model available at: http://anser.org/docs/reports/Tech_Data_with_Real_Options_Spreadsheet_Model.xlsx

[2] Note that in practice, when the need arises for spare parts procurement, the probability of being in a spare parts buy position becomes 1. The probability of need for each year should be regularly re-evaluated based on changes in the projected forecast for spare parts procurement. For example, being in a buy position in one year might increase the probability of being in a buy position for spare parts in subsequent years. The probabilities are not intended to remain static over the entire life cycle.

deliverables. Since this scenario looks at a single data deliverable and focuses on cost avoidance calculations, we omit the cost.

- The TDP data deliverables and associated rights can be purchased for $50,000[3] or rented for one year for $5,000.
- Two courses of action are available when the TDP is not delivered to the government: sole source procurement from the original supplier, or workarounds to enable procurement from other sources without a TDP.
    - If spare parts are purchased in a sole-source environment, the unit cost is $1,000. If they are sourced competitively, there is a cost savings of 25%, for a unit cost of $750 (Office of the Inspector General, 1995).
    - Workarounds include procuring approved substitutes, qualifying a new substitute, repair/refurbishment/reclamation, reverse engineering, and redesign. The average cost of these workarounds is $159,179 for our scenario[4]. This estimate is based on surveyed cost metric data from the resolution of parts obsolescence problems (Defense Standardization Program Office, 2015). These costs can be avoided if the TDP is available for spares procurement. If a work-around is implemented for a particular application, the out-year costs for that application become zero.

Table 1: Probability of Being in a Buy Position for Spare Parts Procurement

Stage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
p(spares)	0	0	0	.5	.5	.5	.5	.5	.4	.4	.4	.4	.3	.3	.3	.3	.2	.2	.1	.01

Using these assumptions, the recursive algorithm calculates the expected cost avoidance for each decision at each time point, starting at year 20, and working backwards to year 1. At each time point, the algorithm selects the optimal decision (buy, rent or neither). This results in the optimal decision path shown in Table 2.

Table 2: Expected Cost Avoidance for Example Scenario

	Expected Cost Avoidance (thousands of dollars)																			
Stage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Buy	0	0	0	209	192	174	156	138	120	104	88	72	55	41	27	12	5	-18	-34	-45
Rent	0	0	0	174	162	149	136	123	110	99	88	77	65	57	47	37	25	17	6	0
Neither	0	0	0	-259	-242	-224	-206	-188	-170	-154	-138	-122	-105	-92	-77	-62	-45	-32	-16	-5

[3] In order to present results that are intuitively clear, we set the discount rate to zero for net present value calculations.

[4] The $159,179 value is a weighted average based on the average cost of each workaround, weighted by the probability of each workaround being selected. The average costs for each workaround were calculated by the Defense Standardization Program Office based on responses collected from the 2014 Defense Industrial Base Assessment: Diminishing Manufacturing Sources and Material Shortages Cost Resolution Values Survey conducted by the Department of Commerce's Bureau of Industry and Security.

In the first three years, since contractor PBL is used, the probability of being in a buy position for spare parts is zero. As a result, in these years, there is no benefit to purchasing or renting a TDP for spares procurement.

In year 4, if the government were to exercise the option to buy the technical data, it would accrue $209,000 in cost savings over the rest of the life cycle, including the benefits in the current year and all expected benefits in the out-years. Buying the TDP continues to be the optimal decision in years 5 through 10. In year 11, however, the expected cost avoidance for buying or renting the technical data is equal. At this point, the combination of low probability of need and limited remaining years of benefit make it equally attractive to meet a need, if one occurs, by either buying or renting the TDP. In year 12 and beyond, renting the technical data becomes the optimal decision.

Monte Carlo Simulation

The business case analysis tool uses expected values as the basis for decisions. In order to evaluate the sensitivity of decisions to the probability of being in a buy position and variability in the cost metrics, we performed two separate Monte Carlo simulations. The first used a uniform distribution to vary the probability of being in a spares buy position between plus or minus .05 of the values reported in Table 1. The results of 1,000 runs are presented in Figure 5.

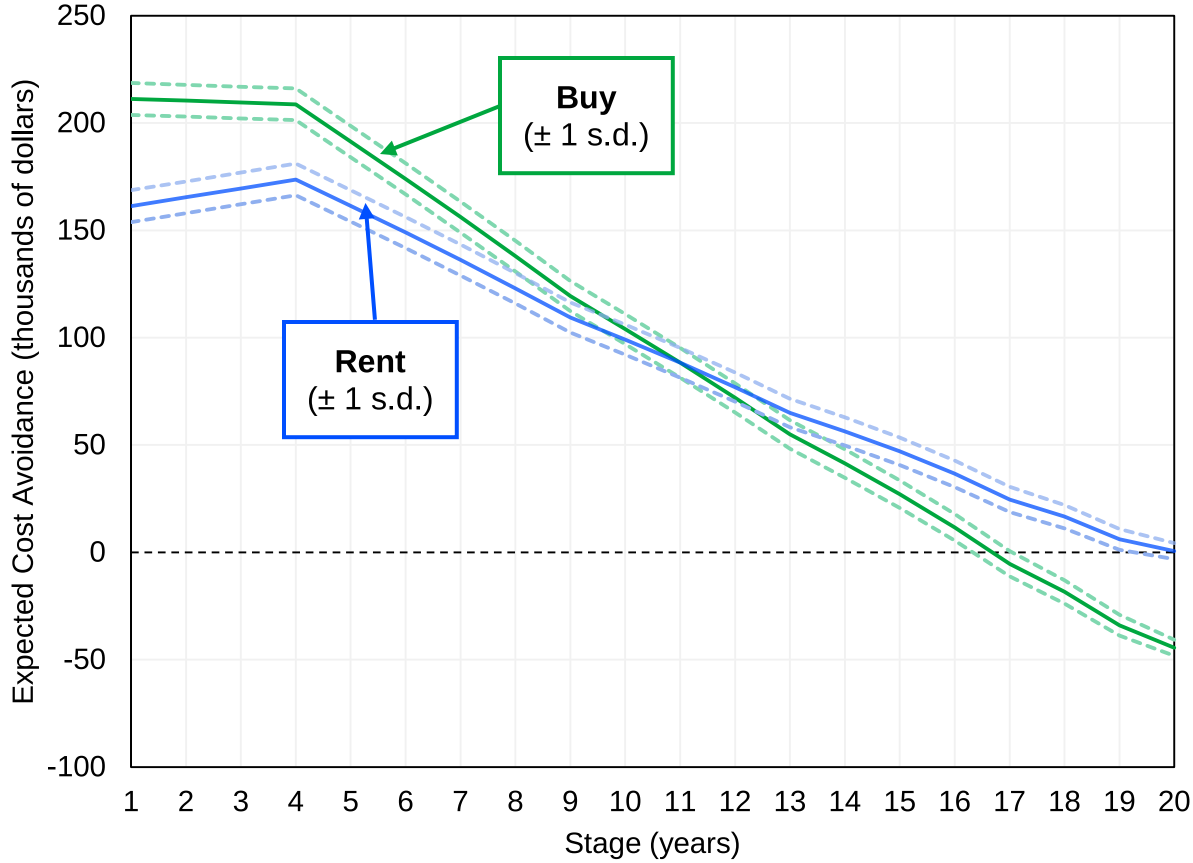

Figure 5. Monte Carlo Results for Varying Probability of Buy Position for Spares

Figure 5 shows the expected cost avoidance associated with buying the technical data at each stage, represented by the green lines, and renting the technical data, represented by the blue lines. The solid lines show the mean expected cost avoidance at each stage. The dashed lines of each color above their mean represent the expected value if the probability of being in a buy position were up to one standard deviation higher than the mean, and dashed lines of each color below their mean represent the expected value if the probability of being in a buy position were up to one standard deviation lower than the mean. The resultant bands show that at the beginning of the life cycle and at the end of the life cycle, as the expected cost avoidance values diverge, the decision to rent or buy is less sensitive to variation in the probability of being in a buy position. Near the middle of the life cycle, however, as the expected cost avoidance values for buying and renting the TDP converge, the decision to rent or buy is more sensitive to variation in the probability of being in a buy position. This shows that as the expected value for renting or buying the TDP becomes more equal, it is especially important to have an accurate assessment of the probability of being in a buy position.

The second Monte Carlo simulation allowed the resolution cost metrics to randomly vary around the mean according to a normal distribution bounded by the 95% confidence interval reported in the Diminishing Manufacturing and Material Shortages report (Defense Standardization Program Office, 2015). Similar results to Figure 5 were obtained. As the expected cost avoidance for buying versus renting the technical data converges in the middle years of the life cycle, the decision is more sensitive to the variation in the resolution cost metrics. These two Monte Carlo simulations show that in the middle of the life cycle, accurate data on the probability of being in a buy position for spares and cost metrics are essential in order to reduce the variation in the estimates and make a more accurate decision to buy or rent the TDP. In the beginning and end stages of the life cycle, an accurate decision can be made even with a higher variance in both the probability of being in a buy position and cost metrics for various resolution alternatives.

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Conclusion

We have proposed a new method of contracting for technical data using options, and a business case analysis tool for decision support in acquisition and sustainment phases. In addition, we have identified the contracting issues to be addressed in both acquisition and sustainment phases, the opportunities to take advantage of technology trends in industry, and the potential for cost avoidance in situations where government needs are uncertain. Finally, building upon the basic underlying decision tree that is present in most real options settings, we have developed and demonstrated a business case analysis tool using a dynamic programming solution algorithm. The business case analysis tool fits cases where the timing of need is uncertain, thereby avoiding the restrictive assumptions of the traditional Black-Scholes model. The Monte Carlo analysis available in the tool can be used to test sensitivity to assumptions and interactions among variables.

While the new acquisition method is applicable for technical data and data rights acquisition to meet the full range of government needs for technical data, we have illustrated its application in only a single scenario—TDPs for competitive procurement of spares and repair parts. Further research could extend the business case analysis to other government application areas, such as engineering analysis, weapon system upgrades, and depot maintenance. The underlying decision support process would be the same for other application areas, but the probability of need and cost avoidance data sources would differ.

Our research was limited by the lack of publically available data. Discussions with DoD practitioners during the course of the research indicated that the year-by-year probability of need could be estimated through a combination of reliability data, parts usage data and expert opinion. Cost data associated with courses of action with and without availability of technical data are also available within DoD, as reflected in the JLTV example cited where a government estimate of $511 million was given for expected life cycle savings if the TDP supported future full and open competitive acquisitions. We were told by both government and industry representatives that the proposed acquisition method has real potential for use, and may merit demonstration in a pilot program.

Ideally, a pilot program would have an established baseline for comparison of the new method to prior methods, and would be executed on a time scale of tens of months rather than tens of years. A weapon system upgrade program might be suitable as a candidate pilot in follow-on research. Key elements to be developed or investigated in such a pilot program might include:

- Solicitation and contract language to incentivize competitive pricing of technical data options
- Identification of data sources for the business case analysis in application areas of interest
- Provisions for government online access to contractor PLM systems, and for maintaining and synchronizing technical data held in separate government and industry systems
- Documentation of costs and savings compared to prior costs for data deliverables and data rights on the system being upgraded
- Evolution of the business case analysis tool, its connection to data sources and its user interface

Finally, we note that real options are widely used as a hedging strategy in the investment sector, but are rarely used in government procurements at federal, state or local levels. The methods and models developed in this NPS-sponsored research are now freely available (http://anser.org/docs/reports/Tech_Data_with_Real_Options_Spreadsheet_Model.xlsx) and applicable to other procurement settings where the public has a long-term interest in sustainment of a capability and a need to mitigate the cost and risk of being dependent on a sole source for the life of the system.

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