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Time Value of Data Decision Modeling for Major Defense Acquisition Programs

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Time Value of Data Decision Modeling for Major Defense Acquisition Programs

Frank Goertner—is Director and Capstone Instructor for the Technology Management Graduate Program at the University of Maryland's Robert H. Smith School of Business. [fgoertne@umd.edu]

William Lucyshyn—is a Research Professor at the University of Maryland's School of Public Policy. [lucyshyn@umd.edu]

Contributors—Jon Crocker, Terrence O'Brien, Joseph Bailey, Wedad Elmaghraby, Harrison Hill, Ryan Huddleston

Abstract

This paper seeks to enhance the Department of Defense's (DoD) understanding of time-value associated with contracted data deliverables and intellectual property (IP), particularly as encapsulated in digital Technical Data Packages (TDPs) for Major Defense Acquisition Programs (MDAPs). Drawing on business contract theory, it examines "economic hold-up scenarios," where imbalances in transaction costs over terms, assets, or IP in controlled, specialized, or evolving markets create challenges. The Defining the Problem section defines the problem as it confronts DoD practitioners today, building on insights from past economic and business research; the How Hold-ups Have Been Addressed in Other Industries section investigates how other industries have tackled hold-ups, situating DoD's challenges within the wider U.S. market; and the Implications for DoD TDP Contracting in MDAPs section evaluates the implications for MDAPs, integrating theoretical frameworks with practical case studies. The paper concludes by proposing a decision model to implement mitigation strategies in future DoD MDAP contracts, accompanied by suggestions for further testing and research to refine this model.

Defining the Problem

Department of Defense's Time Value of Data Challenge

The pricing and procurement of parts for the acquisition and sustainment of the Department of Defense's (DoD) large, complex weapon platforms (MDAPs), regularly precipitate overlapping economic challenges. The specialized nature of components, regulatory structure of defense contracting, and competing interests around intellectual property (IP) rights within MDAPs are factors that commonly distort efficient market transactions between what is often a single DoD customer and a single available supplier.

These challenges are markedly evident in transactions involving *Technical Data Packages (TDPs),* and the resulting inefficiencies are particularly prevalent in their valuation over time. Transacted as a component of the original design, but then essential for both the remanufacture and maintenance of the parts they accompany, TDPs carry some economic value for both the supplier and customer for as long as the platform they comprise remains in service. However, the value they offer at the moment of production, and at any given time thereafter, can vary widely according to part type and fluctuate considerably due to operational conditions, shifting maintenance requirements, or supply chain developments.

This results in a multi-faceted dilemma for many MDAP acquisition strategies. The Defense Federal Acquisition Regulation Supplement (DFARS) mandates that DoD procuring activities develop an acquisition strategy for all major programs and weapons systems prior to solicitation that accounts for projected technical data use over the system's entire life cycle (DFARS 207.1, 2024). Furthermore, the DoD directs program offices to acquire essential IP deliverables and license rights at "fair and reasonable prices," ensuring that the DoD can sustain and upgrade systems throughout all program production, maintenance, and sustainment phases (OUSD A&S, 2019). Yet how should DoD executives value TDP ownership and IP access for millions of physical parts,[1] each with its own predicted life cycle and idiosyncratic variables of operational necessity, produced in scattered manufacturing markets likely to change over the decades-long lifespan of a major weapons platform?

Pricing informed by the manufacturer alone can be costly—inviting maximalist estimates of future expenditures. However, a strategy informed by the DFARs alone may be too generic. It is absurd to think a TDP for a part like a data cable in an aircraft, ship, or submarine—used and replaced often but relatively simple to manufacture with relatively generic IP—should be priced and contracted equivalently to parts in the same platform's specialty propulsion unit—rarely replaced and extraordinarily complex to manufacture with IP potentially at the highest levels of national protection. It is equally absurd, though, to expect DoD procurement professionals to craft individualized valuation guidance for each part and TDP.

Today's DFARS dictates that DoD procuring activities strategize for price efficiency at scale. Yet it offers scant guidance for its decision-makers on execution-level tactics and tools that advance that goal. A look beyond defense contracting may help. What the DoD and its contractors routinely confront is what economic and business researchers refer to as a ***hold-up problem.*** Fortunately, they have also devised several options to mitigate it.

Dynamic or discriminative time-value modeling, real options contracts, and pooled IP access solutions are tools increasingly utilized in the private sector and select government agencies. Each, in its own way, seeks to remedy inflexible contracts and limited IP rights that impede long-term, cost-effective sustainment strategies.

What Is a Hold-up Problem?

According to contract economics theory, a *hold-up problem*[2] emerges when two parties refrain from efficient cooperation because of imbalances in their bargaining power. Hold-ups involve two factors: (1) a requirement for non-contractible specific investments prior to the transaction and (2) uncertainty between parties on the exact form of optimal transaction (e.g., quality, number of units, time of delivery; Rogerson, 1992). These conditions exacerbate the inherent challenges of incomplete contracts (Aghion & Holden, 2011), particularly in markets characterized by high levels of information asymmetry (Lofgren et al., 2002), monopoly power (Lerner, 1934), or consumer monopsony (Weintraub, 1949).

The products and services most at risk of hold-up problems are those with significant asset specificity, which refers to the degree to which investments in a specific transaction for a specific purpose retain value above and beyond their use for any other purpose (Williamson, 1981). Nonspecific assets, whether transacted recurrently or occasionally, typically have external competitive forces of supply and demand sufficient for the commercial market to govern price to some measure of certainty for all parties. However, the more idiosyncratic use a product or service has for a customer, the more asset specificity it assumes.

As products or services become more asset-specific, incentives toward more idiosyncratic and more hierarchical contract governance also grow. Outside markets may not exist for either supply or demand, meaning parties to the transaction only have each other as sources of information and price governance. When these asset-specific transactions are definitive and expected to occur only once or infrequently, both the customer and supplier tend

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[1] While challenges explored here may pertain to digital and physical parts, our scope is limited to physical hardware.

[2] Foundational works on *hold-ups* include ***Markets and Hierarchies: Analysis and Antitrust Implications*** (Williamson, 1975); ***Vertical Integration, Appropriable Rents, and the Competitive Contracting Process*** (Klein et al., 1978); and ***Transaction-Cost Economics: The Governance of Contractual Relations*** (Williamson, 1979)

to have clear incentives to share information and cooperate toward fair contractual pricing. Considering the stakes and cost of the process, private parties often acquire the assistance of a third-party arbiter. However, since it is expected to be a one-time cost with a high reward to both sides, such trilateral governance can often mitigate, or at least balance out, hold-up problems.

Yet when asset-specific transactions are recurrent or long-term, or if asset specificity of the goods or services fluctuates or is disputed due to changes in the external market, hold-up problems can become far more prevalent. Trilateral arbitration of each iterative transaction is often too costly, devolving into bilateral or unilateral contract governance with considerable space for opportunistic information asymmetries and pricing (Williamson, 1979).

Transactions in aerospace and defense industries are a prime example of such transactions. Many involve products or services with little to no value beyond the specific purpose for which they are designed. Their value is highly specific to a single monopsonistic government consumer. However, they demand extraordinary levels of pre-transaction information and investment, limiting viable suppliers to as few as one contractor with considerable monopoly power. Moreover, while the initial contract for the design and manufacture of the first version of a defense platform may be strictly governed, the recurrent transactions for maintenance and sustainment of its mission-specific parts may not. The resulting bargaining imbalances and information asymmetries incentivize contractual relationships riddled with uncertainties around information sharing and price adjustments over time.

Economic hold-ups are common across the DoD because the conditions favoring hold-ups are prevalent in the procurements it pursues. That said, not all hold-ups are created equal.

Types of Economic Hold-ups in the DoD

The highly specific missions supported by specialized platforms that define military procurement, the deep levels of pre-transaction investment in parts and TDPs by uniquely equipped defense contractors that enable it, and the inevitable uncertainty of future market disruptions for both sides offer favorable conditions for hold-ups in the DoD to occur and recur. As outlined above, these hold-ups can be expected to be most prevalent in defense contracts involving recurrent transactions for assets (i.e., products) of high or mixed specificity and insufficient governance of information sharing or market valuation over time.

The relationship between DoD and MDAP contractors in designing, producing, maintaining, and sustaining major weapons systems offers each of these conditions. However, that does not imply there is a single hold-up problem demanding a single analysis or solution. A major weapons platform, such as a Navy submarine or Air Force strategic bomber, is composed of a vast number of parts and processes (i.e., products) that have varied levels of uncertainty and governance. The result of hold-ups for each may be the same—transactional inefficiency—but the solution will likely differ according to its prime factor within it.

For this study, therefore, we identify **three types of hold-ups relevant to DoD contracting, categorized by the primary** factor underlying each (Figure 1).

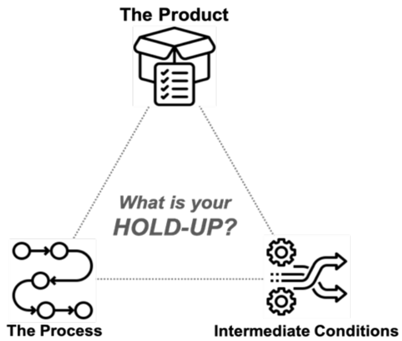

Figure 1.

Product Hold-up: A *Product Hold-up* is a hold-up that derives from asset specificity of a type of product anticipated to retain its specificity in transactions across all current markets and all envisioned future markets. This may be because the type of product is regulated (e.g., radar absorbing materials), the mission for which the product is useful is restricted (e.g., classified programs), or the product is used in a unitarily select purpose for which no alternative market is foreseen to ever exist (e.g., undersea nuclear deterrence). In this case, both a permanent monopoly and monopsony exist, fully disassociating free-market dynamics from influencing product life cycle valuation or transaction leverage between product customer and supplier.

Intermediate Hold-up: An *Intermediate Hold-up* exists when a type of product is transacted as asset-specific in current markets (i.e., there are no known commercial alternative suppliers or alternate uses today). However, the system or its components could be viably transacted under different competitive conditions in future or reimagined markets. In this [illegible] *Figure 1* [illegible]urrent market accommodates monopolistic and/or monopsonistic power. However, tl[illegible] technical or regulatory constraints to innovations or market disruptions that could rebalance future transactions. Perhaps a new, previously non-existent commercial market is emerging, other DoD systems could be designed to use the same part, or new technology like 3D printing would permit new supply alternatives.

Process Hold-up: A *Process Hold-up* is a hold-up that derives from the specificity of the process by which a type of product is transacted rather than any inherent product characteristics. There may be alternative market uses for the product (i.e., competitive demand) or viable alternatives for its manufacture (i.e., competitive supply). Still, the government's transaction process stipulates a unique and specific variant of the product or means by which it must be transacted. In this case, the government's monopsonistic demand for its product and transactions prompts the hold-up rather than the supplier's monopoly over the type of product itself. Perhaps the part is readily available in a commercial off-the-shelf version, or technology already exists for alternative manufacturing methods. However, government regulations either prohibit, fail to incentivize, or insufficiently describe accounting for them in contract pricing and negotiations.

These three categories are not exhaustive of all types of hold-ups, nor are they mutually exclusive. A hold-up can be driven by more than one factor. However, assessing and assigning the primary source and category are necessary first steps in devising potential solutions.

Equally important, time plays a role. A hold-up now may not last forever. Categorization of a hold-up type for a given product may not be static or permanent. For example, a part or its TDP subject to a *Process Hold-up* in an acquisition program's design and production phase could be recategorized as an *Intermediate Hold-up* as the program shifts into a maintenance and sustainment phase.

Time may even change the contractual parameters of the part or TDP across these phases. A bundle of components considered a single contractual product during the design and production phase could be disaggregated into multiple sub-components of contractual products during the maintenance and sustainment phase of the program. In other words, neither assets nor terms of specificity may be assumed to remain unchangeable across the entire life cycle of a platform and program. Any hold-up analysis should be considered a snapshot in time, subject to reframing and often open to disruption.

Options for Mitigating Hold-up Problems

The seemingly intractable nature of hold-ups is rooted in the economic reality that the value of products and services within a market is inherently dynamic. Valuation can rarely be perfectly determined by parties in advance or accurately represented in a static contract between them.

One approach to addressing this hold-up conundrum and rebalancing transaction asymmetries over time is the use of an options contract, an agreement between two parties that facilitates a *potential* transaction involving a contractually defined asset at a *preset* price and date (Corbin, 1914). Options reduce pre-contractual uncertainty while preserving flexibility for both the consumer and supplier to adjust toward an optimal transaction as information mediates risk over time. They offer a negotiated right, but not an obligation, to purchase or sell components of the transacted product or services, the value of which is projected to fluctuate.

While options contracts have been used in various industries to address hold-up problems, their effect derives from the balanced leverage of multiple parties in an otherwise open, competitive economic market. Consequently, this paper limits its exploration of options contracts and their utility to DoD hold-ups characterized as *Process or Intermediate Hold-ups.*

This does not imply that an asset in a *Product Hold-up* for which specificity of use or design is the prime hold-up factor could *never* be considered for an option contract or any other solution explored in this paper. As discussed previously, the nature of a product may change as time and acquisition phases shift. A part and its TDP may be a single highly specific asset subject to a *Product Hold-up* during platform design and production. With time, market evolution or progression into platform maintenance and sustainment can be recategorized as they become less specific. The part or TDP may have the same name, and a hold-up may remain, but the reason, type, and solutions to mitigate it will have changed. In other words, just because a part is not suitable for an option now does not mean it can never be considered for an option later; however, that alone would not invalidate our description of applicability. The key is to retain focus on categorizing the market around the part rather than fixating on any one label for the part itself.

The application of options to mitigate *Intermediate Hold-ups* is reviewed as regularly applied private sector use cases to draw lessons for challenges to the DoD scenarios.

A second approach to disrupt *Process Hold-ups*, particularly those involving IP, is patent-pooling: an agreement among patent owners to license their intellectual property as bundles to each other or third parties (Reisinger & Tarantino, 2019). In highly dynamic but regulated industries such as entertainment, information technology, and medicine, there is evidence that creative agreements among parties to pool patents can serve as a tool to counter innovator hold-up problems without curtailing technological progress (Baron & Pohlmann, 2015).

While U.S. government agencies have not traditionally established their government-sponsored patent pools, the National Institutes of Health has uniquely partnered in select patent pools to alleviate hold-ups for medical technologies critical to public health (National Institutes of

Health [NIH], 2022). The applicability of this approach beyond health technologies is also explored.

Finally, a third approach is summarized that could mitigate Intermediate Hold-ups and Process Hold-ups through a proposed shift in DoD policy to transact for access, rather than ownership, of TDPs. Termed Tech Data as a Service (TDaaS), this approach can be employed alone or in conjunction with an option or patent pooling arrangement.

However, it is important to acknowledge that since hold-up categories are not mutually exclusive, options to mitigate them may not be as well. An optimal contractual solution could incorporate more than one approach outlined above and below (Figure 2).

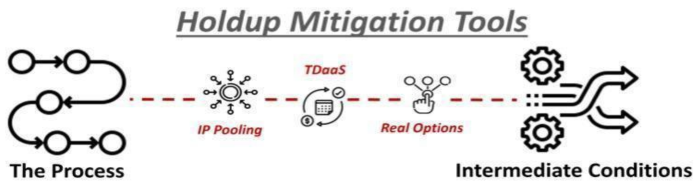

Figure 2.

How Hold-ups Have Been Addressed in Other Industries

Real Options: Pricing the Future of Tangible or Intangible Assets[3]

When considering how to use options contracts best to resolve hold-up problems, it is informative to first briefly review how options have been used in other applications and industries to solve similar problems. Traditionally, options contracts are financial instruments that provide individuals and institutions with opportunities to manage risk, speculate on market movements, and enhance portfolio performance over time. At their core, options contracts grant the holder the right, but not the obligation, to buy or sell an underlying asset at a predetermined price within a specified timeframe. This flexibility makes options contracts useful tools for mitigating transaction risk and planning for market uncertainty in the future. By offering the potential for leverage, diversification, and strategic positioning, options contracts empower market participants to tailor their risk exposure and optimize financial objectives with precision. Whether used by investors seeking to hedge against adverse price movements, traders aiming to capitalize on short-term fluctuations, or companies looking to mitigate future risks to their operations, options contracts have become a widely used and studied tool in the private sector.

Several key elements influence the pricing of options contracts, each playing a crucial role in determining the value of these derivatives. The first input is the *Current Price* of the underlying asset, as options derive most of their worth from an asset's performance as valued within current market conditions. The second input to the option's value is the *Strike Price*: the predetermined price at which the option holder can buy or sell the underlying asset. *Time Until Expiration* is the third input, with options typically losing value as expiration approaches due to diminishing time value. A fourth input, *Volatility*, reflects the market's expectation of future price fluctuations.

By analyzing these elements within shared pricing models, such as the Black-Scholes model (a mathematical model used for pricing options), investors and traders can align assumptions and calculations of time-value and risk across a diversity of products over a variety

[3] Foundational works on *Options Pricing* include *The Pricing of Options and Corporate Liabilities* (Black & Scholes, 1973); *Theory of Rational Option Pricing* (Merton, 1973a); and *An Intertemporal Capital Asset Pricing Model* (Merton, 1973b)

of time-spans (Black & Scholes, 1973). The math can be complicated, but its premise is simple. The agreed *Current Price* of any product transacted today is founded on shared assumptions about market dynamics, or *Volatility*, from now into the future. Yet there is also a reasonable probability that those assumptions are wrong, with the value of that probability corresponding to how well those assumptions match reality as the future nears the present. If market dynamics inflate the product's value beyond expectations, time offers a premium on behalf of the buyer. The seller enjoys the discount if market dynamics depress the product's value below expectations. However, if each agrees up-front to the *Strike Price* that adjusts value for both at a milestone between now and the future—the *Time Until Expiration*—each can split the risk according to their forecasts of how and when the market may change. The contractual option offers a path through an intermediate hold-up caused by uncertainty or doubt (Figure 3).

Though options contracts were born in real estate and financial markets, their applicability has proven useful beyond traditional investing and trading domains. One notable example of how non-financiers have adopted options principles is *Real Options.* In *Real Options*, options are considered more than investment opportunities, but rather *any* real-world opportunity. Analysis of *Real Options,* predicated on some version of the same four input elements—*Current Price, Strike Price, Time Until Expiration*, and *Volatility*—associated with capital projects or business ventures is employed to evaluate investment decisions in uncertain environments. By treating managerial choices as options, real options analysis enables decision-makers to assess the time-value of flexibility and adaptability in strategic planning.

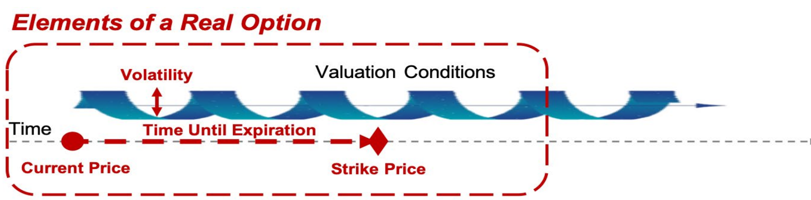

Figure 3.

Patent Pooling: Reimagining the Process of IP Stewardship

Alongside, or possibly between, tangible and intangible assets in the private sector market of valuation and trading stands IP. In an intangible sense, IP represents the valuation of creativity and access to innovation. Yet, a deeply rooted federal governance mechanism—IP patenting—has imbued it with a sense of tangible value nearly akin to real estate. Like a property deed, one can see, even frame, a patent.

In many ways, patents have evolved into their own class of products. A patent may be associated with a tangible or intangible asset it begets. However, it also represents some measure of value on its own—value to the inventor that expended specific investments prior to its award as well as value to a partner that wants to employ its utility, perhaps as or potentially beyond what that inventor envisioned. Both sides want the *current price* of access to the patented IP to reflect the hopes and needs they foresee for the future. However, by definition, future returns are unprecedented and, therefore, uncertain. Hold-ups in IP are common and complex.

One tool that can mitigate intellectual hold-up is embedded options in licensing contracts to access or use IP over time. These work similarly to any of the examples above, albeit with the product patented technology rather than land or a digital coin.

Particularly to patents, however, another tool has emerged to mitigate hold-ups in the transaction of intellectual rights: *patent pooling.*[4] We live in a period of breakneck discovery and high-stakes disruption. One result has been a massive increase in awarded patents in recent decades. Another has been an explosion of litigation between competitors with similar technologies. Such conflict in court is often a byproduct of Process Hold-ups that derive from governance or government procedures that struggle to keep up with the complexities and quantities of transactions a market demands.

As a type of technology advances in time, increasingly complex products need to draw on a widening span of IP for their design and production. This can drive *royalty stacking,* a market inefficiency where a single product must bear multiple royalty burdens to satisfy licensing requirements across complimentary but dispersed IP. This, in turn, can drive patent trolling or patent hoarding, whereby firms pursue strategies to monopolize patents to maximize their leverage in hold-ups.

Patent pooling preempts the incentive to prompt such hold-ups. Within patent pools, two or more patent owners agree to share access to their IP and the potential to license it to others jointly. This enables innovative technologies to be developed by more producers at less cost, accelerating the commercialization of the IP along with future market conditions of shared benefit to its owners, producers, and customers. If options contracts offer pit stops or offramps on the road from today's market to that of the future, patent pools repave the road to smooth and quicken the ride.

For example, within the biomedical industry, patent pools have been used successfully to advance technological progress in the creation of tests and medications for both HIV (Lampe & Moser, 2016) and COVID-19 (World Health Organization [WHO], 2023). The resulting market for new treatments and drugs has benefited consumers while profiting manufacturers and even seeding ground for new adjacent markets the technology can spur. That said, their efficacy on hold-ups depends on the motives of the poolers. If collectively, instead, they prefer the future to be slowed, they can also be used to defend the status quo. This was the case for movie film manufacturers in the United States in the early 20th century when Technicolor and Kodak pooled patents in collusion to inhibit the development of technology that could erode current pricing conditions for their high-revenue products (Lampe & Moser, 2016). In this case, the pool was a place for the hold-up to fester.

Tech Data as a Service (TDaaS): New Process and Options for Data Access

A final approach explored in and around the DoD with potential application in addressing hold-ups is a proposed shift in policy to transact for access, rather than ownership, of intangible assets: an approach coined by some as *Tech Data as a Service (TDaaS)*.[5] TDaaS aims to meet DoD challenges in the acquisition and management of digital assets such as TDPs at a sustainable cost that accounts for the value of those assets at the time they are needed.

Within the current DoD procurement process, government acquisition professionals are required to maximize the purchase of TDPs and associated data rights during the design and production phase of a platform. The goal is to assure availability to minimize risk in anticipation

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[4] Scholarly works on the evolution and impact of patent pools include *Patent Pooling and the Anti-Trust Laws* (University of Chicago Law Review, 1950); *The Design of Patent Pools: The Determinants of Licensing Rules* (Lerner et al., 2007); and *Patent Pools, Competition, and Innovation—Evidence from 20 US Industries under the New Deal* (Lampe & Moser, 2016)

[5] For a seminal work exploring the adoption of TDaaS for the DoD, see *Technical Data as a Service (TDaaS) and the Valuation of Data Options* (Thompson & McGrath, 2019).

of future uncertain needs across the life cycle of the parts and platforms they support. Clearly, the ingredients are all there for a hold-up problem to endure.

What if, instead, DoD contracted with the inventors and suppliers for priced access and use of that data when needed? Similar to Software as a Service (SaaS), which has become ubiquitous among contracts in commercial IT (Mell & Grance, 2011), TDaaS contracts could break down bilateral hold-ups by changing the process governing the transactions in which they occur.

There are four specific potential advantages to the adoption of TDaaS. The first is to allow for quick and accurate purchase, lease, or access to TDPs and their digital subsets as the needs of the government customer arise. This “pick and choose” method of continuous procurement allows for monetary savings by avoiding an all-or-nothing up-front approach, as is current common practice. Second, the government gains adaptability to future needs by allowing a method to keep the door open with the contractor in an environment of uncertainty regarding future data needs. Third, it allows for more dynamic price modulation according to the changing conditions of shifting market or operational conditions over the lifespan of a platform and its parts. Finally, it incentivizes the contractor to maintain and update TDPs throughout the entire system’s life cycle, ensuring the DoD has access to the most current part specifications.

The importance of addressing such DoD hold-ups and the prospect of federal-level change as it relates to TDPs and data rights in general is evidenced in their inclusion in the National Defense Authorization Act for Fiscal Year 2024, H.R. 2670, 118 Cong. (2024).

This all points to one certainty on the path from today’s market to the ones that will follow. More tools are needed for the government and its partners to price their transactions over time amidst rapidly changing conditions and governance.

Implications for DoD TDP Contracting in MDAPs

Each of the industries, cases, and approaches presented in the previous section are unique. However, components of each offer insights into how the DoD may mitigate future hold-up costs as it negotiates rights over TDPs within MDAPs.

As described in the Defining the Problem section, the DoD must contend with a variety of economic hold-ups in the acquisition of parts and access to associated TDPs necessary to build and sustain major weapons platforms such as submarines or bombers over a multi-decade lifespan. The dynamics of rapidly evolving technologies, industries, and markets compound the inherent complexities of assessing net value and negotiating fair prices for a mix of tangible parts as well as intangible digital and IP assets within government contracts regulated by the DFAR. Standard practice is for the many hold-ups that derive to be confronted and cemented en masse in a few or single MDAP contracts for platform design and production.

Are Real Options an Option for DoD Intermediate Hold-ups?

The DFARS establishes that the DoD can include negotiated options in MDAP acquisition strategies. Despite this, real options are rarely employed. In fact, our research could not identify a DoD major weapons systems program to have used contracted real options for component parts to any considerable degree.

The most intractable obstacle DoD acquisition professionals face in employing options for parts or TDPs appears to be in their pricing. As outlined in the How Hold-ups Have Been Addressed in Other Industries section, options pricing in the private sector relies on quantifiable valuation measured in transparent, competitive markets. Within the Black-Scholes Model, shifts in market forces and factors impacting the *Current Price* can be combined with *Price Volatility* projections under calculated probabilities and assumptions across the *Time Until Expiration* to generate an optimal *Strike Price.*

In the monopoly-monopsony market of many DoD MDAPs, pricing works differently. For example, the DoD contract for the Navy's new Columbia Class Ballistic Missile Submarine (SSBN) is an Integrated Product and Process Development (IPPD) contract (DoD SAR, 2023) with a single standard for pricing, a Cost Plus Incentive Fee Approach (AFCEA, 2020). The *Current Price* is calculated as a sum of allowable supplier costs plus a negotiated fee, which is adjusted by a formula comparing total allowable costs to total target costs. However, identifying life cycle data needs early in the development of a program like this can be challenging. Deferring some amount of payment for TDP access and maintenance to an optionable future date would change the timing and accounting of contract deliverables, allowing the government to access only necessary TDPs when they are needed. That could generate efficiencies, but those may not translate into net dollars saved.

In order to adapt the hold-up mitigating potential of real options contracts to DoD contracting in this case, the Navy would need tools to account for forces and factors beyond supplier cost that may impact the price valuation of contracted components over time. One example of such forces and factors is monetary inflation. In the simplest construct of "risk-free" options pricing, interest rates alone are projected across the *Time Until Expiration* to establish the future *Strike Price*. This enables both parties to account for their own assumptions about inflationary pressure on the cost of capital and price over time.

The use of options by the DoD to hedge against inflation alone is unlikely. DoD acquisition policy for Cost Plus Incentive Contracts already controls for inflation versus profit (OUSD[A&S], 2022). Yet inflation is not the only force or factor to impact prices over time, especially in technology manufacturing and support industries such as this.

Trends in technology development and adoption suggests economic forces and technical factors can be expected to place both upward and downward pressure on per unit cost, and therefore price, over time. Even in closed, non-competitive monopoly-monopsony markets such as the current one between the Navy and its sole supplier of nuclear submarines, General Dynamic Electric Boat (GDEB), the benefits of scale should pressure marginal costs per unit down over time. One-time fixed design costs, such as TDP creation, along with recurring fixed production and sustainment costs, such as TDP maintenance, may be distributed across a larger set of priced transactions as the fleet of platforms grows and ages. Traditionally, this force derived from a scaling economy may have seemed irrelevant within a DoD program sourced solely by its own defined requirements, and U.S. government allocated funds. However, the potential for economic scale over time beyond pre-programmed requirements suddenly enters the equation as the manufacture and transfer of nuclear submarine parts to other countries, such as Australia and the UK, becomes possible (Australian Government, 2024). On the other hand, risks that the U.S. submarine industrial base cannot meet scaling demand or that demand for infrequently replaced parts is too sporadic to sustain subcontractor cash flow over time could inject new scarcities that pressure costs up.

Forces of technological change can add pressure as well. Complex systems with precisely engineered mechanical parts may be simplified or enhanced with new alloys and materials. Parts that must be molded and milled today could, in time, be additively manufactured either by contractors or directly by the Navy. Processes that demand skilled human labor today may be automated in the future. Various technological advances of various types are poised to disrupt wide swaths of the U.S. manufacturing industry in ways and at speeds we can foresee but not forecast with precision. In some cases, these changes may drastically reduce the cost of remanufacturing parts. In other cases, they may expand the breadth of eligible suppliers or supply techniques. They could even eliminate many of today's barriers and costs associated with forming a new business for a short-fused demand after an unanticipated market exit.

Each of these factors and forces is a source of potential asymmetric uncertainty about the future market between the Navy and GDEB or the DoD and any sole MDAP contractor. Were they in an open competitive market, these asymmetries would be balanced and distilled through competing bids by auction into an equitable *Strike Price* over an agreed *Time Until Expiration*. The contracted real option would then alleviate the hold-up by either side.

Elements of a Notional Real Option for MDAP Parts and TDPs

For the DoD and an MDAP supplier, bilateral negotiations between economically informed parties would need to set the price. To start, DoD acquisition professionals need variables they could independently quantify as cost-risk proxies in place of the *Price Volatility* used in Black-Scholes.

These variables would reflect the degree to which future forces and factors could drive the cost-value of a part or its TDP up or down in time. Next, they would need to assess the optimal *Time Until Expiration* for the real option according to their analysis of how rapidly those factors and forces will have a production or sustainment phase impact (Figure 4).

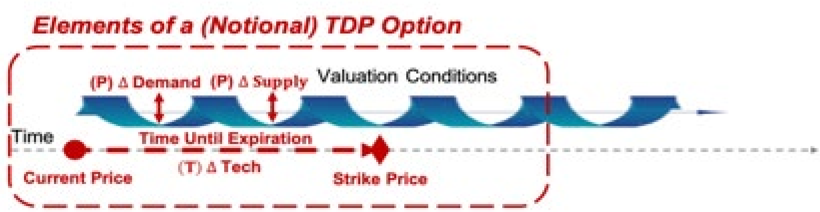

Figure 4.

Proposing specific sub-variables and equations is beyond the scope of this study and will be left to future research. However, extant research publications and private sector sources can offer a place to start. The potential monetary impact from changes in supply could be projected by assessing the savings the DoD could potentially realize in the maintenance and sustainment phase of a program, should they acquire both the rights and capabilities to reproduce the parts themselves. Additionally, scenarios for new manufacturing efficiencies or alternative suppliers could be modeled and assessed for their probability and impact on cost, either for part replacement or TDP reproduction. Like the private sector, a blend of historical data from predecessors or peer MDAPs and pro-forma analysis from industrial technologists and economists can be informative. In the case of Navy and GDEB, this could include data from the Ohio Class submarine program that the Columbia program is replacing.

The potential monetary impact from changes in demand could prove both simpler and harder. At a minimum, design and production phase executives would need to consult with maintenance and sustainment phase experts to assess the margin of error in replacement schedules for each major component and TDP. From our interviews with subject matter experts, this is something that already happens, but not always with the persistence, precision, and documented quantification this level of independent modeling would demand. The more challenging task may be forecasting potential changes in demand for the MDAP platforms over time. For example, the Navy's shipbuilding plan within any given budgetary cycle will always be the official projection of record for number of SSBNs demanded. However, the probability of future contract modification, such as the modification awarded in 2022 for Columbia Program expansion (General Dynamics, 2022), could theoretically be assigned with derivative effects projected on per-unit replacement price. As the United States reevaluates both force sizes and uses, such projections could be timely.

Finally, assessing the optimal *Time Until Expiration* could be the most complex variable to assign. Again, private sector business practices may offer some leads. Technology and market projections are available from both commercial and government sources. For the DoD, the Intelligence Community can help, as can technology consultants versed in enterprise transformation and industry-level valuation.[6] Summed and assessed, these variables could be used in options modeling prior to additional modification for MDAP design and production phase or additional contracts in maintenance and sustainment phases of a program.

Could a "TDP-Library" Circumvent Process Hold-ups?

In today's evolving technological landscape, many TDPs also represent commercially valuable IP, the rights for which can also lead to a process hold-up. When the DoD fails to acquire the necessary IP to operate and maintain its weapon systems, the hold-up often increases costs over time (GAO, 2021). The 2021 case of TransDigm offers a case study of how IP hold-ups can even be exploited to extreme ends (DoD-IG, 2021).

Applying private sector approaches to pooled IP management, three methods for consolidating and managing DoD TDPs and IP data rights merit attention: (1) IP pooling within the DoD; (2) establishing a non-profit IP consortium; and (3) delegation of IP governance to an independent commercial vendor.

IP Pooling within the DoD

One way to reconfigure the data-rights processes that prompt hold-ups in DoD transactions would be to establish a separate DoD program office tasked to pool shared IP management and TDP maintenance across all phases of MDAP design, production, maintenance, and sustainment. This is not a large deviation from the way the current process is supposed to function. However, the DoD office or agency, in this case, would be "pooling" IP and data access assurance as a "library" service independent of MDAP contract requirements. An advantage would be that familiarity with defense-specific requirements, protocols, and security measures would ensure compliance with federal regulations, reducing the risk of regulatory breaches and ensuring all data is managed according to defense and international trade standards.

Establishing a Non-Profit OTA Consortium

The Other Transactions Authority (OTA) framework has emerged as a flexible and streamlined approach to fostering innovation through partnerships between the DoD and the private sector. Through OTAs, a non-profit consortium could be established as a neutral entity dedicated to developing and implementing standardized data rights and TDP management processes. By bringing together key stakeholders from industry, government, and academia, the consortium would work to standardize processes, enhance data security, and facilitate innovation while ensuring the availability of the TDPs to all relevant partners.

This standardization would serve to level the playing field for current and future suppliers, reduce the administrative burden on industry and the DoD, and widen competitive innovation among small businesses and non-traditional contractors. It may be affiliated with or similar to the existing Defense Industrial Base (DIB) Consortium.

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[6] This past year, the DoD announced a $2.4 billion contract for Deloitte, a leading accounting and consulting firm, to explore options to expand submarine workforce development as well as accelerate the development and adoption of more modern manufacturing supply chain techniques (Wilkers, 2024).

Delegation of Authority to a Commercial Vendor: An IP/TDP Escrow

Using a commercial vendor to manage the DIB IP and TDP library may be an effective alternate strategy. Contemporary vendors (e.g., Exostar) bring the latest technologies and specialized expertise, utilizing tools such as cloud computing, AI, and blockchain to enhance data management, security, and accessibility (Exostar, n.d.; Henderson, 2020).

This approach mirrors a tool widely used by both Amazon and Walmart—the IP escrow—in which a third party holds the vendor's data and data rights in an escrow account. If an original supplier goes out of business, discontinues the product, or fails to perform on the part of a contract, the buyer ensured sustained access to the data and data rights (Sander, 2022).

To implement an IP/TDP escrow for MDAPs, the DoD could require contractors to deposit comprehensive TDPs[7] into an escrow account when acquiring complex weapon systems (Figure 5). By securing these TDPs through escrow, the DoD ensures that the government can access the necessary information to sustain the system independently if the contractor is unable or unwilling to provide support. The DoD can protect its interests by adopting escrow agreements while fostering better collaboration with industry partners (Sander, 2022).

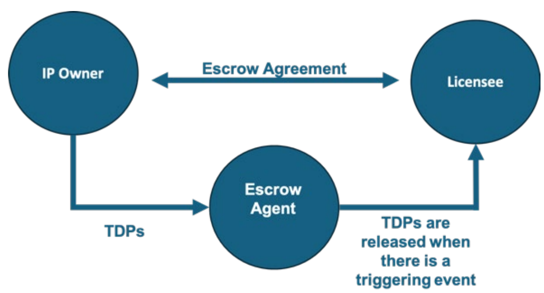

Figure 5.

Is TDaaS Worth Piloting in a Future MDAP?

The final approach introduced in the How Hold-ups Have Been Addressed in Other Industries section as a mitigation to some measures of both *Intermediate Hold-ups* and *Process Hold-ups* in MDAPs is a proposed shift to transact for access, rather than ownership, of intangible assets: considering *TDaaS*.

As outlined in our exploration of *TDP Libraries*, OTAs enable experimentation in contracting without requiring the rewriting of the DFARS. Yet, as discussed in the exploration of Real Options for MDAPs before, simply rescheduling payments of parts with prices locked by Cost Plus Incentive Fee contracts merely spreads out the impact of the hold-up rather than addressing it. TDaaS offers an "all of the above" approach that, in some cases, may prove to have the most effect.

Imagine a service-based contract for TDP access and maintenance that incentivizes the manufacturer or supplier and sustains their survival, but with a real option priced to account for the probability of use beyond the first most likely replacement period of the part as well as probability spread among new manufacturing techniques, supply chain efficiencies, and modified demand. If the part and its TDP include IP declared Government Purpose or Limited

[7] The TDPs can include models, drawings, specifications, performance requirements, and software documentation for system maintenance and future upgrades.

Rights, the option may account for the potential of a future OTA consortium or TDP library eclipsing the hold-up.

If the market or IP sharing arrangements evolve in the DoD's favor, the most efficient transaction for both sides could be for the Navy to execute the option to terminate the service agreement and either maintain and use the data itself or transfer it to the consortium. On the other hand, electing to forgo the option harms neither the mission nor the industrial base. The service contract would continue to economize both access and business support through the sustainment and maintenance phase of the program.

Of course, this could prove cost-prohibitive to negotiate and sustain for every part. However, for those with frequent replacement projections subject to hold up of acquisition processes known to be unsustainably unaffordable or risky, it is worth piloting to try. At worst, it will force cross-program collaboration and standards on acquisition and technological projections for critical parts and data as Columbia migrates from design to sustainment over the next half century or more. At best, it could pave the path to true innovation in MDAP acquisitions.

Which Tool for What Hold-up? A Proposed Decision Guide

Assuming the DoD adopts all of the above, the next question at hand is: Which one should apply for each type of hold-up originally identified within the Defining the Problem section? The challenge here is defining the dimensions of asset specificity with regards to part and TDP, and what approach is best suited to mitigate the hold-up to which it is subject.

First, it must be recognized that not all parts necessarily require special attention to the valuation of access or purchase to the rights to their design data or IP. Depending on the type of hold-up, the asset specificity of the part, and the economic and intellectual property considerations, a maximalist approach to government ownership or access rights is likely not practical. Second, it is important to acknowledge that a large number of parts in many MDAPs are likely best contracted for and acquired as currently done. Yet, if a subset of parts could benefit from the new Time Value of Data approaches outlined above, how can they be identified and matched to a solution? Another approach borrowed from corporate best practices may be the answer: a decision matrix.

Sketching a DoD Decision Matrix for Time Value of Data

Decision matrices serve as decisional guides rather than policies or procedures. Through a series of questions, the strategist is invited to dissect a complex, multi-faceted dilemma into addressable decision bins. Economists and corporate finance professionals often guide the way through acquisition decisions, financial modeling, and negotiations that could have enterprise-wide enduring effects.

A robust decision matrix for MDAP Time Value of Data decisions, along with more refined modeling of Real Options Pricing, will remain a rich area for research beyond this present project. We conclude, however, with some thoughts on what such a decision matrix could include. For the sake of this model, the matrix is represented as a "decision cube" (Figure 6).

Figure 6.

Decision 1: What is the Hold-up?

This first question, more than any of those that follow, demands creative and consequential deliberation. At first pass, every part and TDP in an MDAP will likely seem fit for categorization as a Product Hold-up. If they are presently crafted and supplied in the monopoly-monopsony market and subject to previously defined data rights decisions, it is easy to assume that they could never be supplied or managed otherwise. The key is to think past current circumstances and ask if the current hold-up is grounded in forever exclusive and immutable conditions related to the type of part or its use.

The first question is: *Could you imagine any future in which the part or its components could be produced by alternate suppliers (including the DoD), or current suppliers could sell the part to alternate customers?* If YES, there is likely a hold-up at play, at least in part, on account of Intermediate Market Conditions. This would be an *Intermediate Hold-up*.

The second question is: *Could you imagine use cases or alternative supply options for the part or its components today if not for the present contract or data rights constraints?* If YES, there is likely a hold-up at play that derives from the DoD acquisition process as presently regulated or applied: a *Process Hold-up.*

Note that the answer to both questions could be YES, in which case you have components of both an *Intermediate Hold-up* and *Process Hold-up* sourcing contract inefficiencies potentially worth mitigating. However, if the answer to both questions is NO, then you are likely constrained by a *Product Hold-up,* in which case the remainder of this decision matrix is unlikely to help.

Decision 2: Is the Hold-up Worth Mitigating?

For *Process Hold-ups* and *Intermediate Hold-ups,* the decision matrix of mitigation tools can be thought of as an eight-binned cube (Figure 6). However, not all the bins will likely merit attention. For any DoD program, the key metric that tends to drive scale from production through maintenance and sustainment phases is the rate of consumption, or frequency of replacement, of parts. Because consumption, or replacement, in turn, drives the enduring value of those parts' TDPs, that can also serve as an indicator for the exigency of a new approach.

If a part contracted for acquisition in the design and production phase of the MDAP is intended to last the full lifespan of the platform, there is likely little value in dedicating decision time to contemplating new tools for better contracting and maintenance of its TDP. That is not to say low-consumption parts are not critical. On the contrary, they may be the utmost essential components for the military mission. However, if access to repetitive supply of either the part or its data is likely, it may not be worth isolating individually for focus.

Decision 3: What Solution-Bins Make Sense?

Narrowing the focus to the top four bins of the cube based on overall projected consumption, or usage rates, of the parts and TDPs across the life cycle of the program, the next decision becomes which tool, or combination of tools, outlined in this report may be best suited to mitigate the particular characteristics of the *Process Hold-up* or *Intermediate Hold-up* in question.

The next question is how to think across the bins to select the mitigation solution that fits best. Starting with an evaluation of two broad hold-up variables may help: Part *Specificity* and Part *Complexity*.

In general, parts that are less specific and less complex (i.e., more easily transferable for supply beyond initial contractors) offer the most opportunity to apply Real Options to transactions involving the parts' TDPs. For those with higher specificity but still low complexity, it may be more reasonable for the DoD to purchase or pursue Unlimited Rights to the TDP up front.

For parts that are more complex, either in terms of construction or IP, it is likely less favorable for the DoD to secure and maintain their TDPs independently. Therefore, collaborative approaches that share both cost and risk, such as IP pooling or TDaaS, could be better options.

Decision 4: What Tool Fits Best?

As discussed in the How Hold-ups Have Been Addressed in Other Industries section and the Implications for DoD TDP Contracting in MDAPs section, a cascading decision model should not be interpreted to imply that the categorization of hold-ups or choosing solutions to mitigate them is an exercise in checklists or mutual exclusion. The questions and decisions above could often lead to a place on the cube seemingly between or across two solution bins. How to proceed then?

In this case, zooming into the decision space to apply other variables introduced in the earlier sections could help.

For example, consider the case in which the hold-up over a part and its TDP lands DoD decision makers weighing whether to purchase or pursue unlimited rights to the data versus attempting to craft, negotiate, and price a TDaaS arrangement. The complexity of the part will be one variable to consider, but it would not be the only one (Figure 7).

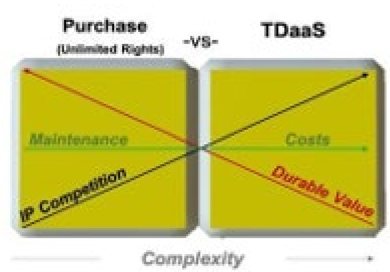

Figure 7.

Additional factors would be how competitive the contractor would consider the IP associated with the part and its TDP. The higher their competitive proprietary interests, the higher price they will likely seek to extract for unlimited rights. Another factor along the same axis would be the estimated cost to maintain and secure the TDP, as well as update it over time. High IP competition and/or data maintenance costs would tip the scales in favor of a TDaaS approach.

Thinking in reverse, however, durability of design and TDP relevance over the life cycle of sustainment could also make a difference. TDPs for parts likely to be wholly redesigned in time may have limited durable value, the lower of which the more favorable TDaaS could be.

Next, consider the seam between a Real Options approach and pursuing an IP Pool (Figure 8). Again, complexity is an important first variable. However, since the Black Scholes thinking is part of the equation, it may be worth breaking that complexity into sub-variables that make up or accompany it.

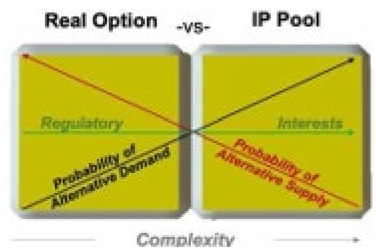

Figure 8

A byproduct of complexity will be Probability of Alternative Supply. The lower the likelihood that the market itself will change on account of new supply-side competitive pressures over time, the less a Real Option makes sense and the more an IP Pooling regime could be attractive.

On the other hand, the higher the likelihood of alternative demand, perhaps from other countries or other DoD programs, the higher the incentives for both the current supply and other parties to enter a pool. The same goes for regulatory interests. The more complex and widely impactful the regulatory interests embedded within a Process Hold-up, the less likely a bilaterally negotiated Real Option will drive meaningful change and the more likely a permanent consortium may be welcome.

Third, zoom into the Specificity axis for a look at the seam between IP pooling and TDaaS (Figure 9). Here, in scenarios more likely influenced by Process Hold-ups rather than Intermediate Hold-ups, Probability of Alternative Supply and Probability of Alternative Demand reorient their vectors. As the probability of future alternative demand options increases, the probability of downward price pressures increases, and DoD equities in a TDaaS approach grow (compared to a permanent IP pool). In the same direction, the higher the maintenance costs of the TDPs, the more sense it makes for a TDaaS subscription model that alleviates the DoD of those burdens.

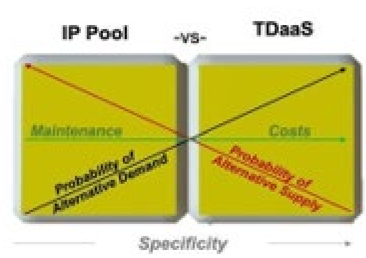

Figure 9.

Conversely, the higher the Probability of Alternative Supply emerging in the market over time, the more an IP pool makes sense, which can accommodate and even accelerate other suppliers, compared to a TDaaS arrangement with today's single source.

Fourth, on the same axis, is the decision space between a Real Option and the Pursuit or Purchase of Unlimited Rights up front (Figure 10). Here, as between other bins, Maintenance Costs of the TDPs over time need to be considered, with higher cost projections tipping the scales toward an Option.

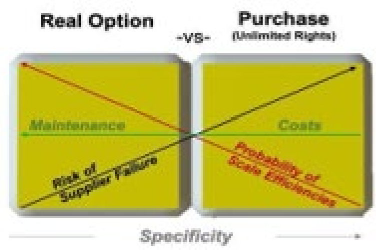

Figure 10.

Beyond that, two new variables merit inclusion. One is the Risk of Supplier Failure. The higher the risk that the market is insufficient to sustain the supplier in business from design and production through maintenance and sustainment, the more value there is to the DoD in securing the data upfront. On the other hand, the more likely technology or other developments could introduce scale efficiencies in production over time, either for the current supplier or new ones with new methods, the more it makes sense for the DoD to focus on valuing Real Options to buy time for those impacts to emerge.

Finally, it is worth thinking again of diagonal decisions across the top of the cube. Zooming into the seam between IP pooling and pursuing or purchasing unlimited rights for the data draws into relief the role of Complexity and Specificity in deciding between IP pools and unlimited data rights (Figure 11). Securing full rights and responsibilities makes the most sense when Specificity is high, but Complexity is low. Whereas IP pools are best when Complexity is high, but specificity is low.

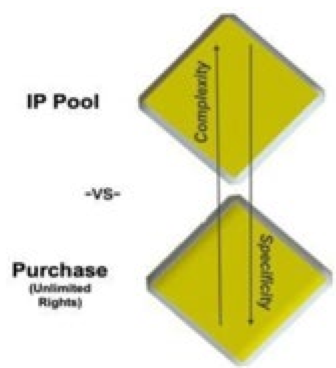

Figure 11.

The last seam is that between Real Options and TDaaS (Figure 12). This diagonal gives a new perspective on something already explored. Real Options and TDaaS may complement each other and can go hand-in-hand. A Real Option could include TDaaS or vice-versa. However, where to start may depend on the same variables just discussed. Low specificity and complexity may suggest a Real Option base. Conversely, High Specificity plus Complexity may suggest TDaaS from the start.

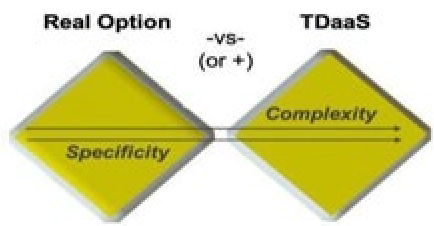

Figure 12.

Conclusion

This paper sought to apply contract economics theory and applied research on hold-up scenarios to challenges in DoD valuation of TDPs and IP in dynamic time-bound markets. The parallels may be imprecise, and the tools abstract, but the study elevates five points of insights and recommendations for the future:

1. **Many parts merit many tools.** In any complex MDAP, there is a risk of being overwhelmed and contractually paralyzed by mass. Millions of parts with varying values, projected lifespans, and data infrastructures cannot be transacted on their own terms. On the other hand, the risk of oversimplification must also be acknowledged. Assuming all components and their TDPs should be priced and acquired en masse, all priced as single type contract or bundled under broadly claimed usage rights carries considerable long-term consequences. Whether or not the tools and guidance outlined above are the right ones for the DoD to adopt, choosing among several will always beat "one size fits all."
2. **Cost-based pricing handicaps options.** If there is a single first step the DoD could make to improve its positioning vis-a-vis both *Process Hold-ups* and *Intermediate Hold-ups*, it is to start weaning wherever possible from Cost based pricing as the default approach. This will be neither immediate nor simple, but OTAs can help. Experimentation in this space may be the single most important foundational step toward further experimentation with Real Options or TDaaS on a measurable scale.
3. **Public-private IP pools are underexplored.** Challenges in IP management across the DoD are a topic of wide discourse. However, the majority of the discussion appears to be focused on policy and regulatory reform. These may overshadow the exploration of more collaboratively disruptive organizational solutions like IP pools. Additional investment and experimentation in his arena may be worthwhile.
4. **Further interdisciplinary study is warranted.** This project offers a theoretical decision framework derived from economics and business research as applied in other industries. The validity and functionality of the framework merits testing within real DoD acquisition scenarios. That should include both historical cases, from which assessments can be made on the impact it could have made, as well as an analysis of its feasibility in current and future MDAPs. If validated and summarized, examples of real-world applications would also serve to make a more robust decision guide more concrete and relatable to future acquisition professionals. In addition, the models and variables proposed deserve more mathematical attention. The use of real options and dynamic valuation models in the private sector has flourished because quantitative metrics and methodologies have been developed and accepted by both suppliers and consumers as fair and transparent. Sharpening future assessment tools for volatility factors like the risk of supplier failure, probability of alternate demand, life cycle data maintenance costs, or technological obsolescence would advance decision-maker confidence in choosing the right tools.

5. **Even the best model is not enough on its own.** An assertion echoed throughout interviews for this research is that no model, tool, or guidance alone will prompt the cultural reform needed to drive change. In many cases, legislative authorities exist and the DFARS allows acquisition professionals to explore and experiment with many of the approaches proposed. The barriers to trying are both systemic and personal. DoD incentives for cost versus performance across all program phases, as well as expertise management through rotations of military personnel, are enduring issues in need of attention.

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