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Balancing Access and Protection: A Decision Framework for Additive Manufacturing Intellectual Property Rights in Defense Acquisition

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Balancing Access and Protection: A Decision Framework for Additive Manufacturing Intellectual Property Rights in Defense Acquisition

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Abstract

This research addresses the challenge of managing intellectual property (IP) rights in defense additive manufacturing (AM) acquisition. Specifically, the Department of Defense must balance operational requirements for IP access against defense industrial base companies' interests in protecting valuable IP assets. We introduce a decision framework to navigate IP complexities in AM applications, encompassing scenario screening, AM lifecycle analysis, IP asset identification, and strategic considerations for acquisition. The framework employs real options theory to provide acquisition professionals with structured guidance while maintaining strategic flexibility, demonstrated through a "Demand Surge" vignette examining a scenario where the DoD must rapidly increase the supply of a proprietary respirator mask beyond the original equipment manufacturer's production capacity during a crisis. Our results indicate that effective IP management in defense AM requires careful consideration of mission requirements, technological capabilities, and stakeholder interests, revealing critical decision points in the AM lifecycle where IP strategy significantly impacts program success. This research contributes a systematic approach to IP strategy development, promoting both fair compensation for IP holders and sustainable defense capabilities while identifying avenues for future research.

Introduction and Background

Intellectual property (IP) rights are a critical concern in Department of Defense (DoD) acquisitions. Obtaining and licensing the correct IP ensures that systems remain operational, sustainable, adaptable, and cost-effective (DoD Instruction 5010.44, 2019; GAO-22-104752, 2021). Thus, the DoD must obtain appropriate IP and technical data rights to operate, maintain, and sustain the capabilities it acquires from the defense industrial base (DIB). Without sufficient IP rights, the DoD may face issues like vendor lock, limited ability to source upgrades or repairs competitively, and surging sustainment costs (GAO-23-105850, 2023; Peters, 2022; Wydler, 2014). However, DIB companies view their IP as a valuable capital asset representing significant investments, thereby becoming a source of market competitiveness and future income. DIB entities aim to protect their IP rights to preserve their asset's monetary value (Hickey, 2022; Peters, 2022). As a result, the varying viewpoints on IP rights between the DoD (seeking access) and DIB entities (seeking protection) lead to tensions that require delicate handling (Tsutsui, Shi, et al., 2024). Therefore, the Purdue research team undertook the research, recognizing the pivotal role that IP rights play in DoD acquisitions and the impact on ongoing operations and sustainment (DeLaurentis, Biller, et al., 2024), which complements work on digital transformation in defense (Panchal et al., 2023, 2024; Tsutsui, Atallah, et al., 2024), as IP rights and digital implementation are intrinsically linked in acquisition.

Another opportunity involves the recent progress in additive manufacturing (AM) and three-dimensional (3D) scanning technologies. This includes addressing rights and compensation for IP holders in AM and determining suitable methods for identifying and incorporating these considerations into contractual agreements (Vogel, 2016; Widmer & Rajan, 2016). Therefore, effective IP management for AM is critical for ensuring a successful defense acquisition. However, the IP landscape within the AM domain presents significant challenges, necessitating a structured approach for effective navigation. Hence, we propose a greenfield approach to navigating negotiations for IP accounting for the uniqueness of AM. This effort was conducted with the notion of being able to work either in tandem or post-hoc integration with existing processes within the DoD.

Managing IP rights in AM for defense acquisitions presents challenges as government operational requirements often conflict with contractors' IP protection priorities. This paper addresses these challenges by presenting a decision framework tailored to the complexity of IP in AM applications, covering scenario screening, AM lifecycle analysis, IP asset identification, and strategy options. To demonstrate practical application, the framework is illustrated through a "Demand Surge" vignette, serving as a guide that blends theoretical insights with practical applications to strengthen AM IP management in the defense acquisition process.

Methodology: Proposed Decision Framework

The proposed decision framework aims to provide DoD users with a structured and informed decision-making process in IP acquisition for AM projects. An overview of the framework is shown in Figure 1. The framework consists of three steps as follows:

1. Scenario screening and scoping: to determine framework applicability and extract relevant use case information
2. IP asset identification and considerations: to ascertain the why (impetus), what (scope), and how (modality) of IP acquisition
3. IP strategy formulation: to consolidate the information and considerations and formulate the IP acquisition options and overall acquisition strategy

The rest of this section details each step and outlines the rationale and pertinent considerations in using the framework.

Scenario Screening and Scoping

The scenario screening process serves as the initial step to determine whether the proposed AM IP framework is appropriate. It is important to note that the framework is not meant to be used in cases where IP compensation is secondary to urgent operational needs or IP protection has expired or does not exist. For those cases, it may be more practical to consider other approaches like reverse engineering or leveraging the Defense Production Act where suitable.

Typically, the acquisition process encompasses several stages:

- Requirements definition
- Market research and supplier identification
- Supplier negotiations
- Contracting
- Development
- Production/Sustainment
- End-of-Life management

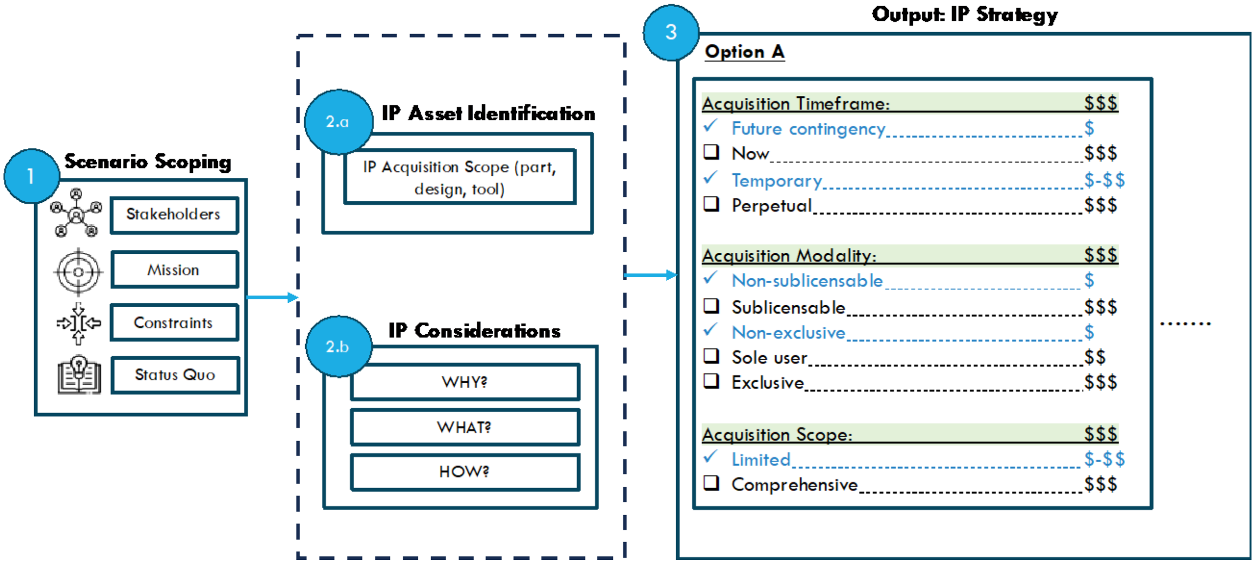

Figure 1. AM IP Strategy Decision Framework

The proposed framework is designed to be implemented during the supplier negotiations phase, ensuring that all negotiations made during this phase incorporate provisions for future IP acquisition rights. While the framework is expected to be applied during contracting, the actual scenarios it anticipates have not yet occurred at the time of framework application. Therefore, the framework should be used to develop preemptive strategies for swiftly acquiring existing IP of additively manufactured processes and parts in the future.

Once the scenario screening has been verified, the scoping process is the next step for extracting and synthesizing information from projected scenarios. This process involves: synthesizing the key elements of the scenario, clearly defining the problem statement, and listing any relevant assumptions and constraints that influence the decision-making process for IP strategy. To effectively address the scenario, the following scoping features must be defined:

1. OEM and Manufacturing Status: Anticipating the impact of future scenarios on OEM efficacy and potential manufacturing capabilities.
2. Part/Process sourcing: Identifying potential substitutes to the part/system to procure (if any).
3. IP Acquisition Requirements: Identifying DoD needs and requirements for IP acquisition.
4. Mission Time and Resource Constraints: Determining time-sensitive and resource-dependent factors.
5. Mission Criticality: Assessing the importance of additively manufactured parts or systems to the mission.
6. AM Capability Location: Identifying the need for in-theatre and/or out-of-theatre production and maintenance.
7. IP Rights Status: Identifying technical data AM parts or systems protected by IP, including ownership of rights.

With these scoping features delineated, a systematic approach was developed to identify the relevant details, which are cataloged in Table 1. These features set the baseline requirements that inform the management of IP assets and considerations and ultimately guide the final IP strategy formulation.

Table 1. Scenario Scoping: Systematic Method for Extracting Information to Inform IP Strategy

Scoping Category	Scenario features
OEM Status	Active or Inactive?
Manufacturing Status	Ongoing or discontinued?
Sourcing	Single-sourced or multi-sourced?
IP Acquisition Requirements	What are some needs/requirements that the IP acquisition strategy must fulfill?
Mission Status and Criticality	What are the timeline and criticality of the mission?
AM Capability Location	In-theatre or Out-of-theatre?
IP Rights Status	What parts, processes, and tools are protected by IP, and who owns the rights?

AM Lifecycle and IP Asset Identification

Surveying the vast landscape of protected assets and then identifying the relevant ones for the acquisition effort is the next step in configuring an acquisition strategy and compensation. To ensure comprehensive identification and reduce oversight, the product manufacturing lifecycle is utilized as a guiding mechanism and followed by a step-by-step vertical exploration in each of the lifecycle phases (i.e., design, build, post-process, testing, Maintenance/Repair/Operations [MRO], and end-of-life) to produce a portfolio of acquirable/needed assets.

Figure 2 depicts the lifecycle of an additively manufactured product and the possible IP assets involved at each phase of the lifecycle. For example, 3D models and digital design assets are identified in the Design/Planning stage of the product lifecycle. Similarly, unique maintenance processes and/or data assets are identified under the MRO phase of the lifecycle.

The assets are categorized (see Figure 2 legend) based on their nature into design, process, software, part, and tool IP. This enables modular acquisition strategies that are either demanded by the scenario or based on already acquired assets. Users have the freedom and flexibility to approach the asset grouping for acquisition either by manufacturing phase or IP area.

While the lifecycle outlined in Figure 2 details the stages and associated IP assets in additively manufactured products, it is crucial to recognize the practical scope of AM within larger systems. Typically, not all components of a product or system are suitable or cost-effective for AM. Instead, specific parts or components are identified as viable candidates for AM due to their design complexity or customization requirements. Therefore, negotiations for AM-related IP rights often represent just one facet of the broader strategy to acquire comprehensive data and IP rights.

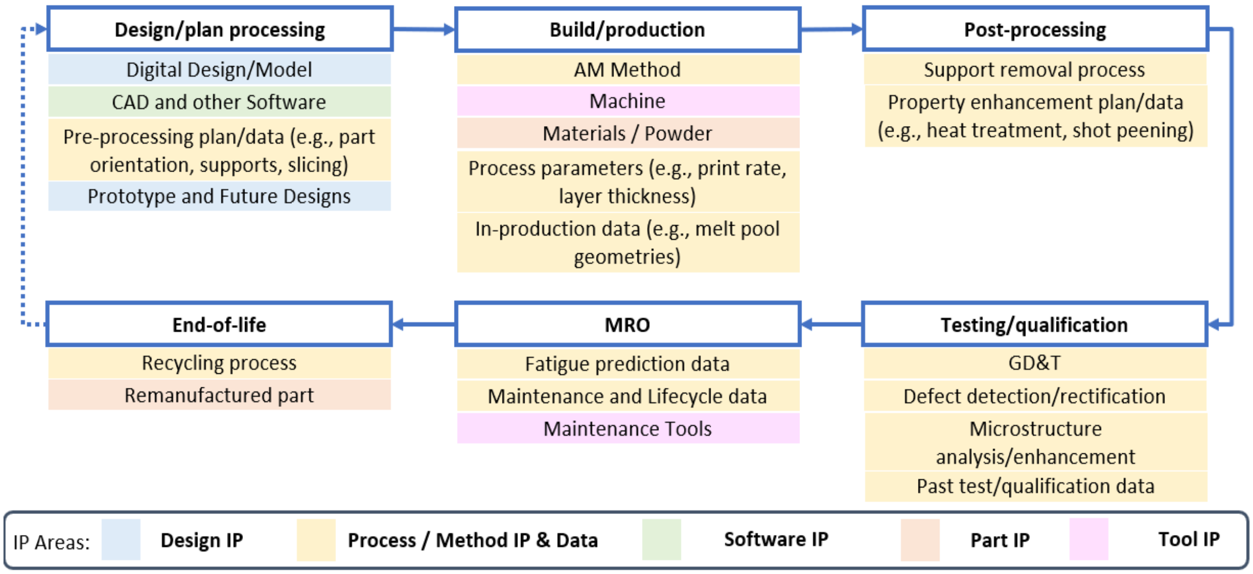

Figure 2. IP Assets in the AM Lifecycle

The assets listed in the framework schematic are not meant to be universal and/or exhaustive. Each acquisition effort will result in a unique asset portfolio based on the objective of the acquisition. First, if the objective is centered around in-use/deployed systems but needs new strategies for end-of-life management, the assets needed to carry out the operation are all identified within the MRO and end-of-life phases. The government can ignore the IP assets in the earlier phases while negotiating with the supplier. Contrarily, if the government is interested in a single-use product, it would buy assets concerning the first four phases without paying attention to MRO and end-of-life IP assets. Finally, suppose the government is interested in procuring a completely new product with no previous production and is planning on using said product for multiple years/cycles. In that case, all aspects of the lifecycle must be considered, and all assets must be carefully selected. The section titled What IP Assets Should Be Acquired? also discusses additional qualitative reasoning that helps choose from the identified assets based on mission needs and constraints.

It is also worth noting that identified assets may or may not have the same type of IP protection. The design of the framework is inspired by and accounts for the following types of IPs: Patents, Copyrights, Trademarks, and Trade Secrets. Knowing the type of IP informs negotiation and compensation strategies. Each type of IP has its unique strictness to usage; some can be more readily negotiated than others. For example, trade secrets are often more complicated to negotiate and procure when compared to buying a copyright license or licensing a patent. This a priori knowledge of distinguishable traits among the asset types helps optimally compensate during the acquisition.

AM IP Strategy Considerations

The next step is to use the relevant information from the scenario scoping and IP asset identification phases to ascertain the key considerations driving the AM IP acquisition strategy. The broad categories of considerations are:

1. Why should IP acquisition be considered? What is the value of the IP asset(s)?
2. What IP assets should be acquired?
3. How should IP acquisition be structured?

The rest of this section sets out a series of decision trees and guiding questions to help determine the features of an appropriate acquisition strategy.

Why Should IP Acquisition Be Considered?

In commercial IP trading, the value of an IP asset to the buyer usually refers to the expected benefits (often economic) from owning the asset. For example, it could include revenue growth from new product sales or increased market share from new customer segments. This usually forms the impetus for IP acquisition. Defense-related acquisitions by the government tend to differ from this aspect in that economic gain is not the primary aim. Instead, a more appropriate measure is the inverse "cost of inaction" (i.e., what the government stood to lose if IP acquisition were not carried out). Considerations to ascertain this cost of inaction (Figure 3) include:

1. How mission-critical are the systems/components that rely on this IP?
2. What are the alternatives to these systems/components, and how do their functionalities and costs compare?
3. What is the cost of ownership and opportunity costs of acquisition?

For example, suppose the systems/components that rely on the IP are mission-critical with few comparable alternatives. In that case, the impact of non-acquisition on mission success is likely to be high, resulting in a high cost of inaction. The converse would correspond to a low cost of inaction. In addition, the cost of ownership (e.g., data, system, and manpower upkeep) and the opportunity cost of acquiring the IP provide one benchmark for assessing whether the cost of the inaction provides a sufficient impetus to consider IP acquisition. If these costs far outweigh the cost of inaction, then acquisition may not be a good option, and there is no need to go through the rest of the framework to determine an acquisition strategy.

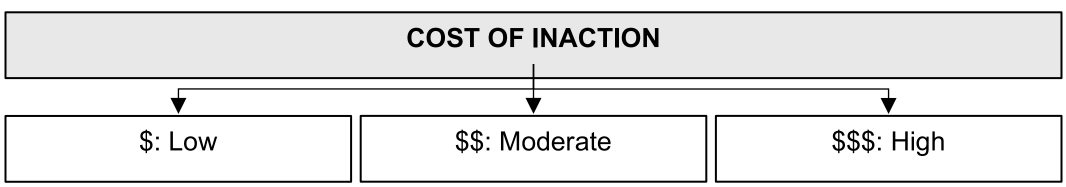

Figure 3. Decision Tree: Cost of Inaction[1]

What IP Assets Should Be Acquired?

Once the impetus for IP acquisition has been established, the next step is to determine the acquisition scope (Figure 4). This requires reviewing the list of relevant IP assets identified in the section titled AM Lifecycle and IP Asset Identification and prioritizing them according to their importance to the mission. Relevant considerations include:

1. What IP is necessary (cannot manufacture without) vs. good to have (makes manufacturing easier)?
2. What are the dependencies across the IP assets, if any?
3. Which parts of the AM lifecycle could be changed to lift the dependency on specific IP assets?

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[1] In these decision tree figures, the number of dollar signs indicate the relative costs of the branches. With use case-specific information, these costs can be quantified to provide a more precise scale for decision-making.

While having a thoroughly ranked list of IP assets will enable a more detailed calibration of acquisition scope, one should minimally aim to classify the assets into those necessary to enable manufacturing and those good-to-have. This will provide at least two acquisition options to suit different scenarios. For instance, a low-priority, low-budget mission may constrain the buyer to acquire the bare minimum IP. In contrast, higher priority/budget missions may require a more comprehensive acquisition scope.

In some cases, dependencies between IP assets (e.g., background IP) may further constrain which IP assets must be acquired together or even warrant all-or-nothing options. Consider whether parts of the AM lifecycle (for the specific system/component) can be adjusted to negate the requirement for one or more IP assets. This could be useful if certain IP assets are costly and/or have extensive dependencies on background IP. For example, the required AM machines, material, and process parameters are constrained by the choice of AM method. For very niche AM methods, there may be few suppliers with sufficient experience and expertise to work out the appropriate production parameters without having access to the relevant process IP. Hence, in evaluating IP acquisition for products that rely on niche AM methods, one may be compelled to consider process IP acquisition (in addition to product IP). One way to avoid being locked into acquiring a suite of IP may be to explore possible changes to the AM method. This would require additional input from stakeholders like engineering teams or AM experts and could thus be resource-intensive. For this reason, it would be prudent to explore options to adjust the AM lifecycle only if the expected IP cost is high or resources allow it.

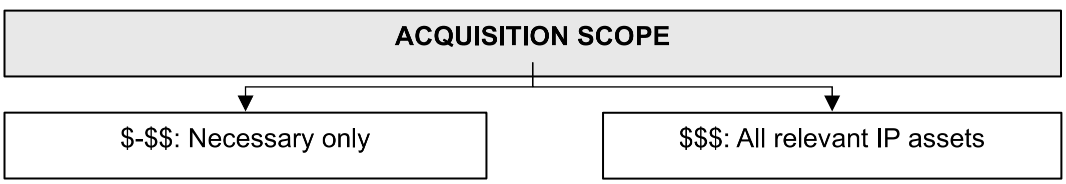

Figure 4. Decision Tree: IP Acquisition Scope

How Should the IP Acquisition Be Structured?

Finally, there are a series of considerations to determine the suitable modality of IP acquisition:

1. When should the IP be acquired (now or as a future contingency)?
2. How long is the data needed for (one-off vs. time-limited vs. in perpetuity)?
3. Are sublicensing rights required in addition to usage rights?
4. How sensitive is the IP – is there a need to limit distribution?

The consideration of the acquisition timing is twofold – whether one should acquire the actual IP now or buy an option to acquire the IP later (Figure 5), and if the latter when the option to acquire should be exercised. The first decision could depend on whether there is any use for the IP, such as creating redundancies in supply chains for strategic goods. The second decision hinges on the lead time required for users to develop the necessary skills and system literacy to use the IP effectively. More complex systems or components may necessitate earlier acquisition to allow sufficient time for capability building. There is, however, a tradeoff with cost – acquiring IP earlier may be a more expensive option due to the higher net present value of money and a longer tail of IP ownership expenses.

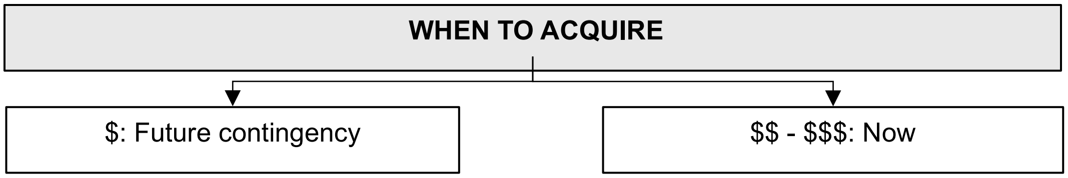

Figure 5. Decision Tree: IP Acquisition Timeline

Factors like the expected mission duration, OEM status, and system/component manufacturing status will drive the required IP use duration (Figure 6). Generally, one might expect the IP use duration to scale with the mission duration, resulting in temporary, time-bound licensing arrangements with the OEM. However, if there are uncertainties around the OEM's operational status or product sustainment capabilities, then a perpetual rights transfer might be a safer arrangement. A perpetual rights transfer option would generally cost more than licensing arrangements, with few exceptions (e.g., OEM liquidating assets below "market value" to manage cash flow/avoid bankruptcy).

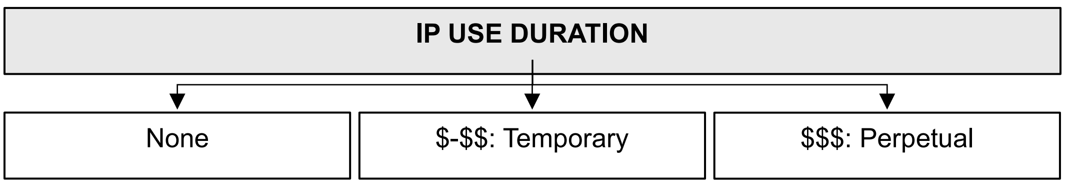

Figure 6. Decision Tree: IP Use Duration

Sublicensing rights (Figure 7) considerations are usually straightforward. It essentially comes down to whether the buyer requires the flexibility to distribute the IP rights to others in addition to using it in-house. This could be driven by the practice of outsourcing manufacturing functions or the need to tap into a wider supplier base to augment manufacturing capacity. In general, we would expect sublicensable rights to cost more since it could mean sharing what might have been the OEM's "trade secrets" with potential competitors, thus eroding some of the OEM's competitive advantage for similar future manufacturing contracts.

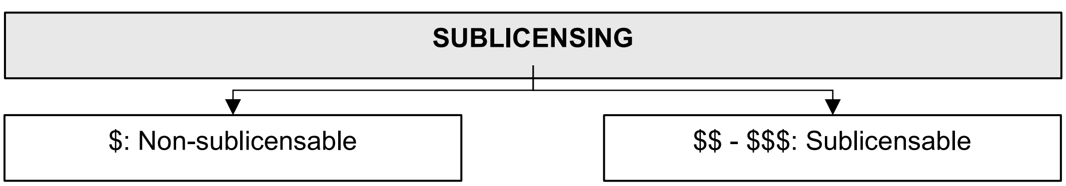

Figure 7. Decision Tree: IP Sublicensing Rights

Finally, we need to consider the level of exclusivity required in IP ownership (Figure 8). In this regard, there are three main categories of IP licenses (Halt et al., 2017; although more detailed calibration of the terms and conditions of IP ownership/use can be crafted using appropriate contractual clauses): non-exclusive, sole, and exclusive. Non-exclusive licenses allow multiple licensees, where the original IP owner can continue to own, use, and sublicense its IP to others. Sole licenses allow both the licensor and licensee to exploit the IP, but neither can sublicense it to others. Exclusive licenses offer the most flexibility to the IP buyer, who essentially would enjoy a monopoly on the IP rights. This option usually also prohibits the original IP owner from using the IP, except for any retained rights (usually non-commercial) provided for in the acquisition contract. The appropriate level of exclusivity will depend on how much control the buyer needs over the IP and the supply chain model. For example, potentially sensitive patents may require higher exclusivity, as information flow may need to be tightly controlled. However, exclusivity may not be a concern without chain outsourcing and sub-contracting restrictions.

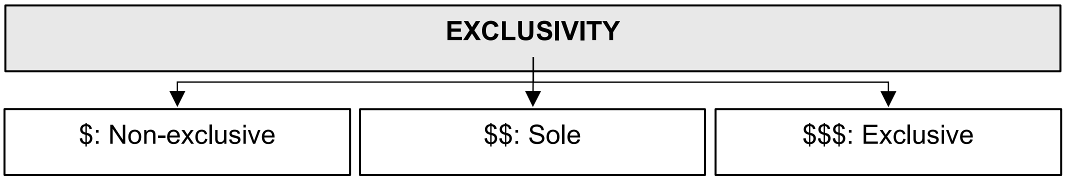

Figure 8. Decision Tree: IP Exclusivity

In practice, where there are sufficient grounds for secrecy (e.g., militarily sensitive information), the government can control IP rights via security classification, export controls, or secrecy orders under the Invention Secrecy Act. There may not be a compensation premium for IP exclusivity in those cases.

AM IP Strategy Formulation

The final step in the framework is to consolidate the information obtained from previous steps to construct an acquisition strategy, which may comprise multiple acquisition options. The underlying principle draws from real options theory, which applies the idea of financial options to quantify and account for the value of flexibility and delay in investment decisions (Trigeorgis & Reuer, 2017; Weeds, 2002). There are many case studies on how real options can be used to support investment analysis of a range of business decisions, such as franchise network expansion (Gorovaia & Windsperger, 2013; Nugroho, 2016) and firm merger & acquisition deals (Čirjevskis, 2024). Here, we borrow the same concept to aid IP acquisition decisions.

Figure 9 illustrates a template checklist (no check marks provided in the figure shown) that is used to consolidate the information obtained from previous steps in the framework. One must check the suitable features to create an IP acquisition option. For example, one IP acquisition option could include features like a comprehensive acquisition scope ($$$), which includes all necessary and good-to-have IP for a future contingency plan ($) for a temporary period (depending on mission duration, $-$$), and with non-exclusive IP rights that can be sublicensed to contractors. This option can be included in the acquisition contract with the appropriate legal language. Based on the flexibility of stakeholder and mission requirements, multiple acquisition options may be possible. In this case, the DoD may (or may not) want to prepare multiple acquisition options that make the IP acquisition strategy.

Acquisition Timeframe:	**$$**
❑ Future contingency	$
❑ Now	$$$
❑ Temporary (e.g., mission duration)	$-$$
❑ Perpetual	$$$
Acquisition Modality:	**$$**
❑ Non-sublicensable	$
❑ Sublicensable	$$$
❑ Non-exclusive	$
❑ Sole user	$$
❑ Exclusive	$$$
Acquisition Scope:	**$$$**
❑ Limited	$-$$
❑ Comprehensive	$$$

Figure 9. A Template Checklist for Acquisition Option: Selecting a Combination of Features for a Possible IP Acquisition Agreement

Results: Decision Framework Demonstration Using a Vignette

We have constructed a fictional vignette to demonstrate the framework application. The distinct features of this vignette aim to cover a specific mission condition for which the framework is applicable but is by no means meant to be exhaustive or representative of specific current or planned DoD activities. The vignette, which is elaborated in the rest of this section, is as follows:

> **Demand Surge**: The OEM may be unable to supply enough resources due to a potential demand surge (e.g., imminent threat and pandemic).

For this vignette, we have made specific assumptions to aid analysis. The recommended acquisition strategy depends on these assumptions and will likely change if these assumptions are different. For this reason, we also conduct a sensitivity analysis on some key assumptions to examine whether and how they affect the recommended acquisition strategy. Nevertheless, this section aims to set out the process of framework application rather than to recommend any specific output produced by the framework. The recommended option, which can be one of several acquisition options, is presented at the end as a checklist. It must be described using appropriate legal language for inclusion in the acquisition contract.

In our research, we also considered two additional vignettes that present interesting applications of the framework: (1) “Limited Access to Original Equipment Manufacturer (OEM),” which explores scenarios where the DoD has restricted access to OEMs due to manufacturing discontinuation or inactive suppliers; and (2) “MRO,” which addresses situations requiring urgent maintenance improvisation due to mission criticality or in-theatre capability requirements. However, due to space constraints in this conference paper, we will focus exclusively on the “Demand Surge” vignette, which provides a sufficient demonstration of the framework’s application.

Overview and Assumptions for the “Demand Surge” Vignette

This vignette explores a hypothetical future scenario of a demand surge for respirators. We assume that the DoD is currently at the supplier negotiations stage with a company called BestMasks (and other potential suppliers) and seeks to prepare an IP acquisition strategy for a possible future demand surge. The vignette sketch is as follows:

"Sometime in the future, US intelligence sources warn of an imminent chemical warfare threat from a large adversarial nation. To combat this threat, the DoD seeks to urgently ramp up the supply of personal protective equipment (PPE) for its troops. A core piece of PPE is a proprietary, best-in-class respirator mask that is additively manufactured by BestMasks. DoD has an ongoing contract with the OEM, BestMasks, for a small supply of respirators required for the Army's Business-as-Usual (BAU) operations (e.g., regular training, emergency response), but the demand surge is expected to far outstrip current supply as well as the OEM's maximum production capacity. A possible solution is to tap into the manufacturing capacity of other respirator suppliers to produce this mask, but these suppliers will need access to IP and other proprietary information owned by the OEM to achieve the high manufacturing precision required for the respirator to function."

To apply the framework, we will make the following assumptions about the vignette:

- The demand surge is deemed temporary rather than a "new normal."
- Although other respirator options exist, the OEM's is deemed the best-in-class and most mission-appropriate model. Hence, the DoD wants to prioritize ramping up the supply of this specific product for maximum mission effectiveness.
- Both product and process IP exist and are required to enable high-precision production by alternative suppliers.
- The OEM owns all relevant IP.
- Alternative suppliers have worked with similar AM methods, materials, and products, such that:
    - They only require a short lead time to start production upon access to relevant IP and proprietary information.
    - With some trial and error, they can figure out the process, post-processing, and qualification parameters for the build.
- The IP required is not subject to invention secrecy protection or export control.
- The supply of filter cartridges is managed separately and not deemed an issue.
- Stockpiling masks is not favored due to high inventory and obsolescence costs.
- Reverse engineering will take too long due to the precision required and may also deter industry from developing IP for crisis-critical products since they risk losing it to the government.
- Hence, a fair IP compensation agreement upfront is desired to facilitate timely supply ramp-up and avoid stifling innovation for crisis-critical products during BAU operations.

Scenario Screening and Scoping

The relevant features of the acquisition scenario, as gleaned from the vignette setup and assumptions, are compiled in Table 2. In particular, we note that IP protection exists from the "IP Status" information. There is also latitude in considering IP compensation issues since the demand surge has yet to occur, and the DoD is not yet in crisis management mode. Hence, this use case has met the scenario screening conditions for framework applicability.

Table 2. Scenario Scoping: Demand Surge Vignette

Scoping Category	**Scenario features**
OEM Status	**Active** / ~~Inactive~~
Manufacturing Status	**Ongoing** / ~~Discontinued~~ • The production capacity of OEM alone is **sufficient during BAU operations** • **Additional capacity needed** to meet demand surge
Sourcing	~~Single-source~~ / **Multi-source** • Other respirator options exist, but this OEM is deemed **best-in-class** and the most **mission-appropriate**
IP Acquisition Requirements	All IP is required for alternative suppliers to **produce** and **qualify** the respirators. • Respirators require **high-precision manufacturing** to function properly • Not “new demand” but “demand surge”: assume DoD already has required IP/knowledge on respirator use, maintenance, and proper disposal • The supply of filter cartridges is managed separately and is not an issue • Suppliers can figure out process, post-processing, and qualification parameters with some trial and error
Mission Status	National priority to ensure the safety and effectiveness of troops • Demand surge is deemed **temporary** rather than a “new normal.” • Stockpiling of masks is not a favored option due to high inventory and obsolescence costs. • Fair IP compensation agreement upfront will facilitate **timely supply ramp-up.**
AM Capability Location	~~In-theatre~~ / **Out-of-theatre**
IP Rights Status	Both product and process IP exist, and OEM owns all relevant IP • General manufacturers require access to relevant IP and proprietary information to attempt production • Assume the lead time to start production is short once manufacturers have access to relevant IP • IP is **not subject to invention secrecy or export control** • Fair IP compensation agreement upfront will **avoid stifling innovation for crisis-critical products** during BAU operations

AM Lifecycle and IP Asset Identification

Next, we need to identify the parts of the AM lifecycle and IP assets that could be relevant for acquisition. From the “IP Acquisition Requirements” information in Table 2, we can infer that:

- IP supporting production and qualification of the respirator mask are required, while
- IP that only supports sustainment and/or end-of-life management is irrelevant since the DoD already has the required know-how from BAU operations.

This means that for this acquisition scenario, the relevant parts of the AM lifecycle are design/plan processing, production, post-processing, and testing/qualification (Figure 10).

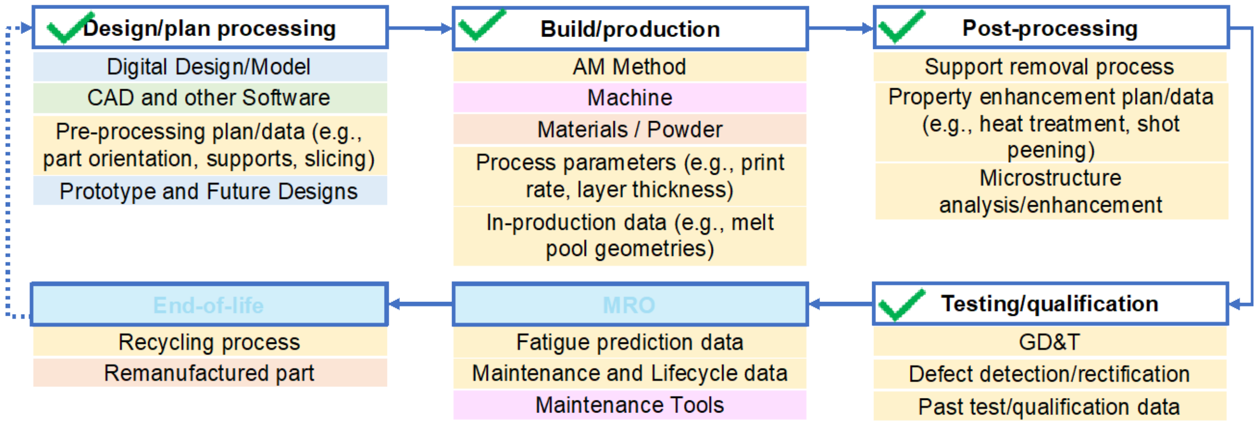

Figure 10. Relevant Parts of AM Lifecycle: Demand Surge Vignette

AM IP Strategy Considerations

The third step is to ascertain the key IP strategy considerations based on information from the scenario scoping step (Table 2).

Cost of Inaction

We start with the cost of inaction. From the "Sourcing," "Mission Status," and "IP Status" information, we can infer that if no IP acquisition is carried out:

- OEM may withhold critical IP/proprietary information from alternative manufacturers, causing delays and gaps in supply ramp-up.
- DoD can consider augmenting the supply with alternative but inferior respirators.

Hence, while the cost of inaction is not as high as it would be if there were no alternative respirator options, there can still be a non-negligible negative impact on troop health, safety, and mission success. This provides sufficient impetus to work through the rest of the considerations to construct an appropriate IP acquisition strategy.

Acquisition Scope

Next, we need to identify the necessary vs. good-to-have IP assets. For this vignette, we assumed that the new suppliers (e.g., other respirator makers) had worked with similar AM methods, materials, and products such that they were able to figure out the process and post-processing parameters, albeit with some trial and error. Hence, we could roughly classify the necessary vs. good-to-have IP as follows (Table 3):

Table 3. IP Classification: Demand Surge Vignette

Necessary	Good-to-have
Digital design/model, AM method/machine/materials	Design software, pre-processing plan/data, prototype designs, process parameters, in-production data, support removal process, property enhancement data, microstructure analysis/enhancement, Geometric Dimensioning and Tolerancing (GD&T), defect detection/rectification, past test/qualification data

From the “IP Acquisition Requirements” and “Mission Status” information, we know that:

- The respirators require high-precision manufacturing to function properly.
- A timely supply ramp-up is desired.

We thus infer that having more information – including the “good-to-have” proprietary production information – would enable new suppliers to achieve the required manufacturing precision more quickly (e.g., less trial and error with the process parameters). This could provide a competitive edge for the DoD, so a comprehensive acquisition scope would be preferable.

When to Acquire

From the “Manufacturing Status” and “IP Status” information, we know that:

- OEM’s production capacity is sufficient to meet demand during BAU operations today.
- Manufacturers only require a short lead time to start production once they have access to the relevant IP, so there is no need to acquire IP far ahead of time to build system capability or train manufacturers.

Hence, it would suffice to prepare a contingency option today to buy the IP when needed in the future rather than to acquire the IP right now.

IP Use Duration

From the “OEM Status,” “Manufacturing Status,” and “Mission Status” information, we anticipate that:

- The demand surge is assessed to be temporary.
- Additional manufacturing capacity is only required during the demand surge.
- OEM’s production capacity is sufficient to meet demand before and after the threat.

Hence, extra manufacturing capacity for the respirator masks is only needed if the chemical warfare threat and the need for U.S. countermeasures remain elevated. The DoD can rely on the OEM’s manufacturing capacity before and after the temporary threat. It would thus be appropriate to consider acquiring or leasing the relevant IP for the expected duration of the mission.

IP Sublicensing Rights

For a demand surge scenario, we can expect the government to want as much manufacturing capacity as possible (e.g., PPE needs during the COVID-19 pandemic). The “AM Capability Location” information also indicates the demand for outside-of-theatre manufacturing needs that the DoD itself can fulfill. It would thus make sense for the DoD to acquire IP sublicensing rights for the flexibility to contract as many alternative suppliers as necessary to ramp up supply.

IP Exclusivity

From the “OEM Status,” “Manufacturing Status,” and “IP Status” information, we can infer that:

- The OEM will continue to be active and contribute as a respirator supplier, requiring continued access to its own IP.
- The IP is not deemed so sensitive or secretive that the DoD needs to tightly monitor and control which entities have access.

Hence, a non-exclusive IP license should suffice in this case.

Summary

Figure 11 summarizes the IP considerations of this demand surge vignette.

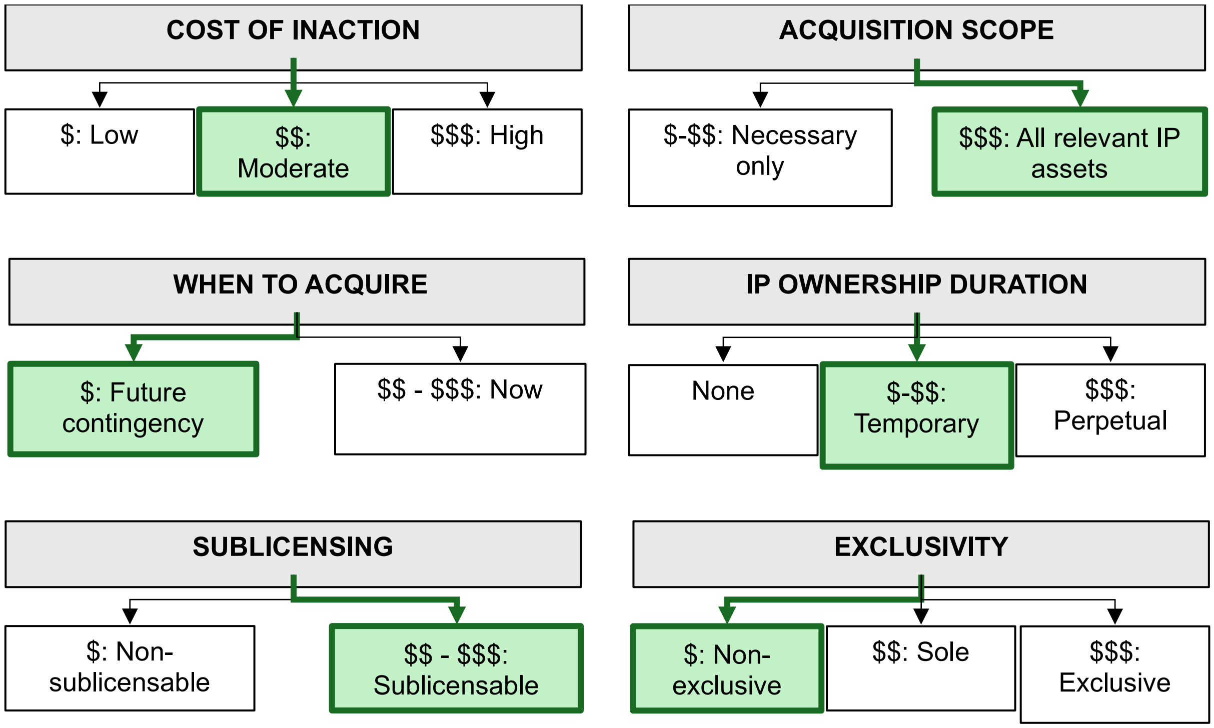

Figure 11. Decision Tree Output: Demand Surge Vignette

AM IP Strategy Formulation and Sensitivity Analysis

Figure 12 shows the acquisition option for the demand surge scenario based on the decision tree output in Figure 11. The recommendation here is to acquire from the OEM, as a buy option that can be exercised in the future, the temporary, sublicensable, and non-exclusive rights to a comprehensive set of IP and proprietary information pertaining to the production and qualification of respirator masks.

Finally, we examine the following variations in assumptions for sensitivity analysis:

Product Substitutability: If the respirator masks were not strictly best-in-class such that fully substitutable goods could be provided in sufficient quantity to meet the demand surge, then the cost of inaction could be significantly lower. The DoD could tap into other suppliers to augment the mask supply using other makes and models that also worked. In this case, there might be no need to own any IP, and thus, no need for an acquisition strategy.

Manufacturing Complexity: Suppose the manufacturing process involved complex and niche capabilities such that alternative suppliers needed a significant lead time to develop the human and system capabilities required for production; in that case, more planning might need to go into the timeline for acquisition. A straightforward option would be acquiring the required IP at the point of contracting and ramping up the strategic manufacturing capabilities required for these crisis-critical products in DIB companies. The tradeoff is higher upfront and retainer costs. Alternatively, suppose the required lead time can be reasonably estimated, and suitable signs that forewarn the onset of the demand surge can be identified. In that case, these can inform the DoD of the appropriate time to exercise the option. Admittedly, the telltale signs of chemical or biological warfare may occur too close to the threat to enable the development of significant manufacturing capabilities. Hence, this option may be more applicable to other demand surge scenarios where trends are more obvious, such as those induced by climate change or population growth.

IP Sensitivity: If the IP is deemed sensitive, such that the DoD needs to exert tighter control on its distribution and use, then a non-exclusive licensing arrangement might not work. Sole or exclusive licenses could then be considered. That said, the sensitivity of the IP will likely align with the sensitivity of the product, such that these patent secrecy and export control issues might be better dealt with outside the acquisition contract.

Acquisition Timeframe: $$

- ❑ Future contingency ______ $
- ✓ Now ______ $$$
- ✓ Temporary (e.g., mission duration) ______ $-$$
- ❑ Perpetual ______ $$$

Acquisition Modality: $$

- ❑ Non-sublicensable ______ $
- ✓ Sublicensable ______ $$$
- ✓ Non-exclusive ______ $
- ❑ Sole user ______ $$
- ❑ Exclusive ______ $$$

Acquisition Scope: $$$

- ✓ Limited ______ $-$$

Figure 12. Acquisition Option: Demand Surge Vignette

Discussion: Additional Complexities and Research Implications

In this project, we have developed a decision framework to determine an IP acquisition strategy for AM systems. While the framework addresses the core considerations of IP acquisition and provides a qualitative decision-making approach, additional complexities merit further study. Future work in these areas could enhance the functionality and applicability of the framework. Specifically, an in-depth analysis of the following areas could significantly improve the framework's usability:

Interface With Existing Acquisition Rules and Processes

While this project was undertaken as a greenfield effort to develop an AM IP acquisition framework, it would be useful to examine how this framework could be adjusted to support and enhance existing defense acquisition frameworks, rules, processes, and decision support systems. For example, integration with the Planning, Programming, Budgeting, and Execution (PPBE) process could ensure adequate resource allocation and financial planning for AM IP acquisition strategies. The AM IP acquisition framework could support the Joint Capabilities Integration and Development System (JCIDS) process in identifying and prioritizing IP acquisition that fills critical AM capability gaps. The framework could also be refined to apply to different acquisition categories, in line with the Defense Acquisition System (DAS) classification, where more expensive programs are subject to more stringent oversight and consideration. Finally, future work should explore and ensure general framework alignment with the Federal

Acquisition Regulation (FAR) and the Defense Federal Acquisition Regulation Supplement (DFARS).

Portfolio-Level Acquisition Decisions

The decision-making process for IP acquisition often centers on their interconnected nature, where acquiring one type of IP can necessitate the acquisition of related IP to ensure full functionality. For example, the DoD might acquire manufacturing process IP that inherently requires the additional acquisition of software IP, like topology optimization. This interconnected acquisition strategy not only highlights the dependency of various IP on one another but also sets the stage for extending these capabilities across multiple missions and throughout the organization. The framework could also support Integrated Acquisition Portfolio Review (IAPR) processes by leveraging the model-based approach to defense portfolio management (DeLaurentis, Panchal, et al., 2024; Tsutsui, Guariniello, et al., 2023).

Sometimes, the interdependencies among different IP are not as straightforward as expected, forcing decision-makers to select from a constrained set of valuable IP due to limitations such as time, budget, capacity, or technological capabilities. For the DoD, this could mean choosing among various sensor technologies that vary significantly in cost, strategic value, or compatibility. For example, the DoD may be more inclined to rely on a single supplier for critical components, thereby reducing procurement flexibility and potentially leading to increased costs if cheaper or more advanced alternatives become available later. This situation is similar to that of consumers entrenched in Apple's ecosystem, where products like laptops, watches, and tablets are designed to work best together, encouraging continued investment within the same brand.

Uncertainty/Risk Quantification to Price Real Options

The current framework provides valuable inference from a qualitative decision-making perspective. However, there is a need to develop a specialized suite of software tools to streamline the IP management process quantitatively to make it more efficient and accessible.

One such tool is based on incorporating uncertainty quantification into the decision-making process to enhance the robustness of IP strategies, allowing for better risk management and more informed choices (Figure 13). These recommendations will contribute to refining the AM IP framework, ensuring the methodology remains adaptable and practical in various defense acquisition contexts. For example, utilizing the current decision-tree structure of the IP considerations and adding random events (e.g., risks, market, and change in status quo) relevant to the scenario allows the DoD to simulate and assign probabilities to outcomes. Simulating outcomes and their likelihood informs the DoD on which options strategy is the best suited or likely to lead to successful acquisition and deployment of the IP.

Additional Considerations for Framework Enhancement

Other considerations that would also be useful to explore are as follows:

IP and Data Qualification: Compared to physical assets, the quality of IP or digital assets (e.g., digital design) may be harder to verify. There may also be dependencies on human or system capabilities to use the assets effectively. This creates an impetus for an IP and data qualification process to validate the integrity of the IP and digital assets. One possible modality is a short post-acquisition "warranty" period where the IP seller must provide transitional support to ensure the usability of the acquired assets. The format and extent of this transitional support would need to be clearly defined upfront. It may also affect the pricing of the acquisition option.

Liability Implications: A related consideration is liability. When IP acquisition results in changes to the supply chain, it could also affect the traceability of liability. For example, suppose the products manufactured using the acquired IP were subpar. In that case, it might be challenging to ascertain whether the fault lay with the IP and digital assets (i.e., OEM's oversight) or how these assets were interpreted and used (i.e., new supplier's incompetence). In addition, a supply change could void any existing insurance policies on the equipment. The liability implications of IP acquisition should also be identified and, if possible, quantified as an acquisition consideration.

IP Compensation Quantification: The decision framework we have developed primarily considers the utility of acquisition to the government based on factors like cost of inaction. This value sets an upper bound for the acquisition price but may differ from the IP compensation that the government eventually pays. The IP compensation amount is dependent on several external factors. For example, the IP owners will have their valuation of the worth of their IP. Competition (or the lack of) from owners of similar IP assets could also affect the market value of the IP. The IP compensation amount may thus need to be determined through a negotiation process with one or more potential suppliers, considering the value to the government and these external factors. A thorough analysis may also be possible using game or auction theory concepts.

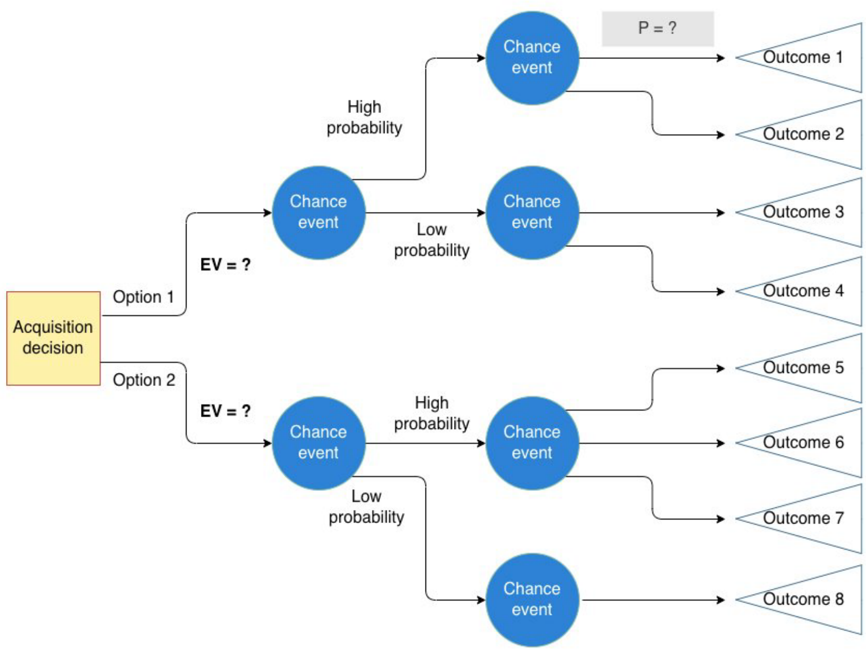

Figure 13. Integration of Uncertainty Quantification in Decision-Making to Enhance the Robustness of IP Strategies and Improve Risk Management

Future Research for Framework Validation and Integration

Future research could also include validating the framework for real-life defense acquisition processes. Implementing use cases based on previous acquisition processes, such as the Joint Light Tactical Vehicle (JLTV) acquisition, would provide valuable insights into what could be done differently. Also, integrating the IP decision framework with an AM decision framework based on real-life AM components (Shi et al., 2023; Tsutsui, Shi, et al., 2023) could provide a new dimension to acquisition research. Collaborating closely with the IP Cadre on current and future acquisition projects can enhance the framework's relevance and applicability. For instance, aligning and integrating the described framework with the DoD's mandatory acquisition pathways is crucial to ensure its practical implementation within the department. Consequently, additional research is required to integrate this framework into the broader Major Capability Acquisition process, ensuring it directly supports DoD acquisition strategies. In addition, examining the IP approaches of other nations, particularly those with innovative technologies developed under constrained budgets (Acquisition Innovation Research Center, 2021), and incorporating them as a part of the AM IP framework can offer helpful strategies and practices for the U.S. defense acquisition process.

Conclusions and Recommendations

IP rights are crucial for DoD acquisition, ensuring defense systems remain operational while avoiding vendor lock and rising sustainment costs. However, DIB companies view their IP as valuable assets, creating tension between the DoD's access needs and the industry's protection interests. The advancement of 3D scanning and AM technologies further complicates this dynamic, making effective IP management essential for defense acquisition and operational readiness.

The paper presented a comprehensive framework for navigating IP challenges in AM within defense acquisition, covering scenario screening, AM lifecycle analysis, IP asset identification, and strategy formulation. We explored the rationale for IP acquisition, identification of pertinent IP assets, and optimal structuring of IP agreements to ensure sustainable defense capabilities and competitive advantage. The framework's application was demonstrated through the "Demand Surge" vignette, examining IP management during extraordinary circumstances like imminent threats or pandemics.

Future recommendations emphasize portfolio-level acquisition decisions, uncertainty quantification, integration with existing DoD processes, and specialized software tools for better risk management. Implementing IP qualification processes, addressing liability implications, and establishing fair compensation frameworks through negotiation will ensure strategic value and successful deployment of acquired IPs across the DoD.

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