Breaking the Iron Triangle with Commercial Technology Insertion

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ABSTRACT

Better, faster, or cheaper? Now, you can pick three. The days of the government leading the charge in information technology (IT) development are long gone, as consumer demand for IT has eclipsed that of the government since PCs entered homes in the 1980s. Sectors drive rapid technology development, which creates opportunities for the government to improve system performance quicker and cheaper by integrating technologies in which the government did not invest long-term RDT&E. The DoD has become more agile in identifying, selecting, and procuring technology through innovation networks and contractual vehicles. Better, faster, and cheaper, right? Almost. This model creates a gap, leading many government programs to fall back on less efficient waterfall systems development and acquisition approaches. Development teams use Agile processes for racing to a minimum viable product (MVP). But MVPs are often viewed as ugly, fragile, and non-scalable solutions. Rather than iterate to achieve the desired final solution, the government often abandons the Agile process and uses the MVP as a reference to form a requirements specification for a *new* solicitation that mirrors waterfall acquisition. Better, faster, cheaper? No. For background, this paper will examine the proven success of the DARPA SIMNET program and the current development of the Integrated Visual Augmentation System (IVAS) to reveal what is possible in terms of cost savings, risk mitigation, and improved capabilities. This paper hypothesizes that government innovation initiatives regularly fall victim to the gap between MVP and scaling, documents the consequences of this issue, and proposes hybrid Agile approaches to close the gap. Partnering with lead systems integrators who are Agile experts and have the requisite mission understanding to accept prudent risk can break the iron triangle to achieve what has been deemed impossible by conventional acquisition canon – a better, faster, and cheaper solution.

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INTRODUCTION

Traditional program management canon dictates that project managers (PMs) are holistically focused on, and constrained by, three factors – cost, schedule, and performance (PMI, 2017). The PM must devote more resources to development to accelerate the delivery of a high-performance multi-featured capability, thereby driving up cost. A PM with a fixed budget and schedule often must sacrifice the number of features or the degree to which they meet the specified requirements. When budget constraints prevent PMs from adjusting quality and performance standards, they will need more time for development.

Therein lies the program management paradox, commonly known as the "iron triangle". The PM and stakeholders may choose to tightly control two of the factors at the expense of the third. Many organizations launch projects, often in isolation, to attain a new capability. Those organizations use their resources and perform on their timetable, ignoring external efforts that may seem unrelated. In this isolationist view, the three factors remain in eternal tension – hence, the iron triangle.

In the case of technology development, government and other public sector projects increasingly can make use of commercially developed technologies. Rarely, however, do these projects realize the full potential of what is available to them. The days in which Defense or Space programs led the way to develop global computational hardware and software systems capabilities are long gone. Once computers became household commodities in the 1980s (Halfhill, 1986), the information technology (IT) development paradigm dramatically shifted, with non-governmental consumers generating the demand and thus driving the capabilities.

An effort to develop networked, distributed simulation capabilities called SIMNET is an early example of what may be possible by adopting technologies developed outside the project's boundary – in other words, through the adoption of commercial off-the-shelf (COTS) technologies. In a paper written in 1995 about SIMNET, the authors concluded:

> *Analysts used to say that users of realistic simulation have a choice of two of the three characteristics of this simulation—fast, good, or less costly—but not all three. ARPA's simulation technology has changed the "rules." The marketplace is teeming with quality, inexpensive programs that can be run on fast, inexpensive hardware to produce realistic graphics. Although programming used to be very time consuming, today's users can purchase commercial off-the-shelf (COTS) programs—all for a few thousand dollars—that reduce from months to days the time needed to prepare the basic code for 3-D simulations (Cosby, 1995).*

Although explicitly written about simulations and with a focus on the computational hardware and software applications required to develop realistic graphics, this idea can extend to all applications of IT and applies to IT domains that were not commoditized in 1995, such as cloud platforms, eXtended Reality (XR), and artificial intelligence (AI). The government spends nearly $20,000 on IT per employee each year, so the potential to reduce costs and improve performance by using COTS products and services is significant (Stegman, 2020).

Integration of COTS technologies allows government PMs and stakeholders to leverage resources, e.g., industry's research, development, test, and evaluation (RDT&E) budgets, outside their project boundary, which decouples developmental timelines and associated costs from the iron triangle. When COTS solutions provide required capabilities, this decoupling creates three interdependent but synergistic lines of cost, schedule, and performance, controlled as variables supporting one another vs. dependencies in tension.

As capabilities become commoditized, we move along the global developmental timeline of commercial IT. As we observe Moore's Law, we find a growing abundance of options for any given capability set, including cloud providers, AI applications, software applications and libraries, gaming development pipelines, displays, microprocessors, and graphics cards. If you chain together the traditional trade-space for each capability set in three dimensions, you begin to envision an icosahedron (see Figure 1) of interrelated capabilities and their associated iron triangles along with other associated factors. Each face starts to have a decreasing surface area, and the number of potential face combinations, i.e., options to integrate the commodity tech, approaches infinity. In this way, the "iron triangle" becomes an elastic sphere, where PMs and stakeholders have increasing control over cost, schedule, and performance parameters. The question becomes less about cost, schedule, and performance and more about feature rollout in an Agile model. An elastic sphere allows program managers to consider feedback and improvements across the development lifecycle vs. locking in on firm requirements. Factor in the ability to buy these IT commodities as a service, and risk is also significantly reduced.

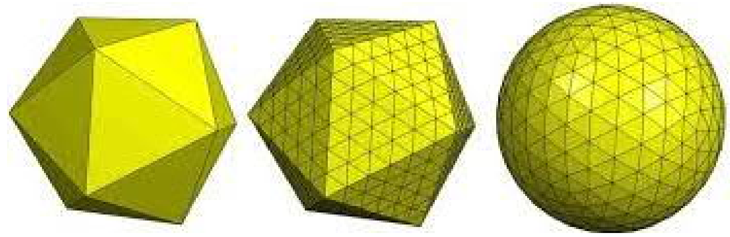

Figure 1: Conceptualizing the Iron Triangle as an elastic sphere of interrelated factors.

The US Army's Integrated Virtual Augmentation System (IVAS) program illustrates the implications of this approach. The IVAS program manager stated that user feedback drives improvements during the prototype phase because "these requirements need to be generated from the bottom up, not from the top down. So enlisting Soldier feedback is really important to us so that we understand what they need and what their requirements are" (Bacon 2021).

Taking full advantage of COTS integration in a government acquisition model can be tricky, though, even with a complete understanding of how commodity technologies change the rules for traditional program management. Traditional government acquisition models use an operational challenge to generate requirements that are reviewed, approved, and ultimately become *static.* Agile acquisition and project management, which may apply to much more than software, keeps the problem statement or desired performance outcome up front. Therefore, as long as a solution is addressing the requirement, it is within scope.

In this paper, we will discuss the successful roadmap laid out by SIMNET and the programs and approaches it originated. We will describe the impact COTS integration and Agile methodologies have on the development of DoD software, outline how today's commoditized technologies continue to expand the number of interrelated factors PMs consider, and then define methods for working within the constraints of traditional government acquisition models to achieve successful COTS integration.

SIMNET

SIMNET is the original simulator networking program sponsored by the Defense Advanced Research Projects Agency (DARPA) in 1983. Reading a history of the technological accomplishments of SIMNET is much like reading an introductory course in live, virtual, and constructive (LVC) simulation. Most LVC terms and concepts, and several codified industry standards, have their roots in the SIMNET program. The most significant is the Distributed Interactive Simulation (DIS) standard, now known as IEEE 1278. Modern LVC modeling and simulation (M&S) events include the Plan View Display, data logger, voice logger, combat vehicle simulators, semi-automated forces, and After Action Review/God View entities (Miller, 2015), which replicate SIMNET's system architecture. SIMNET's impact on military training cannot be understated. However, one of its original intents is common across many DoD training programs – to reduce cost. SIMNET promised to reduce cost by connecting participants remotely, eliminating the need for all participants to travel to a single training location. Modernized IT infrastructures, the continual war for talent, and recent current events surrounding COVID-19 continue to underscore the importance of enabling a distributed workforce, including those in training and education environments. During the program's execution, the team identified the integration of COTS technology as a major factor in their ability to deliver a timely and cost-effective solution (Schneeman, 1999). They used generic high-end desktop computers, commercially available instrumentation boards, and a server system based on the Dell PowerEdge 6300 – the commodity IT technology of the time. Not only did SIMNET embrace the idea of COTS integration, SIMNET incentivized industry investment in the long-haul network, graphics subsystems, and computer image generators (CIGs) for out-the-window displays. These investments paved the way for what is now a multibillion-dollar gaming industry that continues to provide COTS technology, such as fully immersive virtual reality (VR) displays and cloud-based graphics processing, shaping simulation and training today.

Although the term Agile would not exist for almost 20 years, the SIMNET team applied most of the principles from the Agile Manifesto (Beck et al., 2001) in a rapidly evolving body of software, which totaled 1 million lines of code by 1990 (Miller, 2015). The principles the SIMNET team used included:

1. Rapid and frequent delivery of useful software.
2. Daily face-to-face communication between business people and developers.
3. A welcoming attitude toward evolving requirements.
4. Frequent internal and external demonstrations.

By the time it became a program of record, SIMNET had already been demonstrated on 14 major occasions to include before the Senate Arms Committee in 1992 (Miller, 2015). SIMNET eventually became the Combat Arms Tactical Trainer (CATT), led by the US Army's Program Executive Officer for Simulation, Training, and Instrumentation (PEOSTRI), which went on to spawn historic and enduring Army programs such as the Aviation Combined Arms Tactical Training (AVCATT) and Virtual Battlespace (Strauss et al., 2019).

Several key observations in papers written by a few of the most instrumental leaders in the SIMNET program include Dr. Jack Thorpe, James Shiflett, Duncan Miller, and L. Neale Cosby. These observations highlight many Agile development principles and the success and impact of SIMNET on the validity of the principles. Using the construct of Agile development, here are some major insights:

1. Prototype the 60% solution. Thorpe describes the process as "the notion that while we could take a great deal of time studying every design issue, it was considerably more efficient to be about 60% complete and rapidly fabricate a prototype that soldiers could see and touch and tell us what needed to be improved" (Thorpe, 2010).
2. Fast, approximate, and cheap may be better than slow, deliberate, and expensive. Thorpe noted that simulator components were designed and fabricated with a useful life of five years to save cost and time (Thorpe, 2010).
3. People who build successful projects must be highly motivated. It is clear from their contributions both during and after SIMNET, Thorpe, Shiflett, Miller, and Cosby were not only crucial leaders but incredibly motivated and passionate professionals.
4. Close coordination between business people and developers is essential. Cosby points out that the intertwined relationship between General Gorman, who had the vision of how SIMNET would be used, and DARPA lead by Jack Thorpe, who had the technical expertise, significantly contributed to the success of the SIMNET program (Cosby, 1995).
5. Reflect and fine-tune at regular intervals. Thorpe noted that, as the SIMNET team grew, team members left, and new team members arrived, the vision and lessons learned from SIMNET had to be shared. The SIMNET team developed SIMNET U at Fort Knox to regularly bring the team together to share, discuss, and become a better team (Thorpe, 2010).
6. Highest priority is to satisfy the customer through early and continuous delivery. Miller describes how SIMNET was incrementally tested and demonstrated to various stakeholders from General Officers to DoD officials and Soldiers. Once the early prototypes gained endorsement, SIMNET was installed at select Army installations and incrementally improved with more terrain databases, more manned modules, better software, and improved functionality (Miller, 2015).

Fast forward to today, and another Army program, IVAS, is gaining success by applying of Agile principles. In a recently published article by the Army about the IVAS program, the following Agile principles are identified as key contributors to the program's success and accelerated development.

1. Welcome changing requirements. A member of Soldier Lethality Cross-Functional Team, SFC Joshua Braly stated, “Whereas before requirements were generated, in my opinion, inside of silos, we really need the Soldier’s feedback in order to generate a proper requirement that's best for the Soldier, period” (Bacon, 2021).
2. Close, daily cooperation and face-to-face conversation are the best. Co-located representatives from the Project Manager IVAS, Soldier Lethality Cross-Functional Team (SL CFT), Night Vision and Electronic Sensors Directorate (NVESD) and C5ISR Prototype Integration Facility (PIF), PM Stryker Brigade Combat Team (SBCT), PM Bradley, Army Capability Manager Stryker (ACM-S) and Bradley (ACM-B), and industry partners comprise the IVAS development team. This team came together at Joint Base Lewis-McCord (Bacon, 2021).
3. Rapid delivery of useful software drives customer satisfaction. SGT John Martin stated, “This is something that none of us imagined we would see in our careers. It’s futuristic technology that we’ve all talked about and seen in movies and video games, but it’s something that we never imagined we would have the chance to fight with. It’s definitely technology that we are really excited to use as soon as they can get it to us” (Bacon, 2021).

In this section, we described successful implementations of COTS integration and Agile principles in SIMNET and IVAS. In the next section, we will discuss how Agile is influencing commercial technology sales in almost every IT domain and how its principles lead to the concept of consumable software.

THE RISE OF AGILE AND CONSUMABLE SOFTWARE

Published in 2001, the Agile Manifesto prescribed principles and defined terminology that dominated the software engineering field for two decades and set the stage for methodologies such as DevOps and continuous integration and continuous delivery (CI/CD). Fast forward to the 2020s, and a significant focus area of software development is application modernization (AppMod). AppMod programs rely on Agile principles, often with the means to deliver those principles as a commercial line item on DoD contracts by selling highly skilled Agile software development teams who have already created the professional relationships to work together effectively “by the sprint.” Greenfielding, or building new software instead of legacy applications, is a commodity in the same way. Agile was the beginning of a tidal wave of digital transformation shifts that have allowed software to take over almost every IT field (Ritchie, 2021) and has fundamentally changed how PMs and executives alike think about technology. However, these transformations break down around more rigid processes and policies, such as government acquisition. For example, it is relatively easy to estimate and package work performed by a single person or a closely integrated team into a specific timeline or sprint in Agile terms. Federal Acquisition Regulations support the acquisition of these work packages as firm fixed price commercial offerings, thus transferring the risk to the seller. Many rules of thumb exist for performing this estimation for software design and development and extrapolated to additional activities such as technology evaluation, selection, and integration.

Obtaining stakeholder agreement over what constitutes a Minimum Viable Product (MVP) further complicates the process of iterating over several sprints to achieve the MVP, and many best practices exist to help manage stakeholder expectations of the MVP. Once the development team reaches the MVP, however, project sponsors tend to halt the Agile development process to sharpen their pencils on what was previously undetermined – requirements and specifications. This tendency puts the project back into a traditional acquisition paradigm, where project managers use the MVP as a reference implementation to describe requirements and specifications for a more formalized program. Financial and budgetary guidelines further exacerbate this tendency because modernization and generation of software and IT-centric capabilities greater than $250,000 are considered investment expenses (DoD FMR 7000.14-R Vol IIa), which leads to establishing an RDT&E effort, even when the solution/MVP is known. Instead of serving as the solution, the MVP serves to help refine the problem, decompose the work breakdown structure, establish a budget, enumerate requirements, and release a new formalized solicitation. In reality, all problem statement refinements and improvements to the solution could be made directly off the MVP, following tried and true Agile processes.

Furthermore, as part of the justification to receive minimal RDT&E funding, programs must defend a sustainment tail that may never happen. With commodity application development and modernization built through software factories all over America, an application’s useful life and ability to achieve a return on investment (ROI) may occur within a single sustainment cycle – deploy, save, win, dispose. Through this lens, PMs may view software applications, unlike monolithic enterprise systems, as consumable items, like fuel, oil, ammunition, batteries, or pencils, rather than a major acquisition end-item. We can use it until it is no longer needed by the unit and not feel the need to maintain and sustain every software program in perpetuity.

In this section, we described how Agile principles have allowed the commercialization of "by the sprint" software development and proposed consumable software applications. The following section will discuss how technologies entering the commodity market today -- XR, AI and cloud platforms -- continue to expand the iron triangle and influence the consumable software trend.

MODERN COMMODITY TECHNOLOGY

Much like the expansion of PCs into homes in the 1980s, the 2020s are seeing the expansion of XR and AI into our everyday lives. Sales of VR and augmented reality (AR) devices (see Figure 2) totaled 5.5 million devices in 2020 and forecasts project sales of 26 million devices per year by 2023 (Vailshery, 2021). Commodity VR devices, such as the Oculus Quest and the HTC Vive, bring an immersive quality to games, movies, and other entertainment, and reduce social isolation both pre-and post-pandemic, by allowing the user to feel surrounded by an environment without being able to see or hear anything in the real world. VR devices often include controllers to enable the user to interact with the virtual world. Commodity AR devices, such as the Microsoft HoloLens, allow users to view and interact with the real world around them while overlaying images, text, and sounds to "augment" their reality. AR controllers are not necessary because the user can interact with the real world as they usually would. The technological progress of these devices in the modern era of VR is impressive as well. Commercial VR headsets became available in the market in 2016 with Oculus Rift, HTC Vive, and Razer OSVR. 2016 models typically had a resolution of 1080x1200 and a refresh rate of 90 Hz. 2021 models improve those stats, boasting resolutions up to 2448x2448 and refresh rates up to 120 Hz.

Figure 2: VR and AR devices like the Oculus Quest (left) and Microsoft Hololens (right) sold units during 2020.

AI enters everyday life through smart speaker devices, such as Amazon Alexa, Google Home, and Apple HomePod. Approximately one-third of American teens and adults own a smart speaker, which is 22% more than in 2020 and five times more than in 2017 (Inside Radio, 2021). Many smart speaker devices are rule-based "chatbots" that react to questions by determining the primary intent and returning a pre-defined "answer" (Alexandru, 2020). Even this is a significant accomplishment, especially in the bot's ability to optimize natural language processing, a substantial field within the world of AI, in a way other applications could not because of the amount of real world data the devices could collect for analysis and training (Delmolino, 2019). As we move forward, smart speakers will become less rule-based and more AI-oriented, incorporating multiple fields of AI to blend empathy, knowledge, and personality into conversational skills. The technology will use deep learning and neural networks to recognize emotion and produce human-like speech integrated with referenced facts from knowledge databases (Alexandru, 2020).

While less evident to the general user, cloud platforms have become an essential commodity that most smartphone apps, websites, and corporate enterprise applications run on. A 2020-era commercial for Amazon Web Services highlights the well-known businesses, such as Netflix, Facebook, and GrubHub, which use their services. Given the competition between AWS, Google Cloud Platform, Microsoft Azure, and other niche cloud platform providers, businesses have the opportunity to scale at rates never before seen, which brings a competitive advantage to entrepreneurs and other small businesses to use their technology in a disruptive way. Indeed, web conferencing solutions, such as Zoom, and delivery platforms, such as Instacart and even Amazon, could not have scaled to support the demands of the pandemic if not for the commoditized nature of the cloud technology.

The most compelling applications for innovation come from an integration of XR, AI, and cloud platforms, which is why it is critical that PMs, not just their technical staff, have a thorough understanding of the metrics, methodologies, and service options available to them. For example, streaming XR capabilities utilize niche cloud platform services to deliver XR experiences with no on-premises compute requirements. Centralized cloud infrastructures stream the pixels that make up the rendered immersive environment to the XR device for visualization. Streaming XR is new technology, with the first software development kits (SDKs) available in late 2020. Companies experimenting in this technology tend to prototype with multiple SDK offerings to determine the best fit, which is an example of using corporate consumable software only as long as it is valuable, likely until the leaders of the streaming XR race establish themselves.

In this section, we discussed the technologies that are entering today's commodity market. The next section describes the investment approach these companies use to drive innovation and highlights parallels to DoD acquisitions for COTS integration.

AN APPROACH TO ACQUISITION

The companies commoditizing XR, AI, and cloud platforms use corporate strategies to drive innovation and efficiencies by pushing profit and loss (P&L) at the lowest levels (Podolny and Hanson, 2020). Likewise, suppose we empower organizations to procure whichever tool necessary to drive efficiency at the small unit level, to include the development of consumable, tailored software applications and services. In that case, we will aggregate to enterprise savings without the need to establish and fund a large sustainment tail, allowing a more Agile approach to software and technology development and acquisition. Furthermore, groups and units closest to the operational challenge or problem statement will have informed, tailored, deployed, and disposed of these applications. Consequently, adjudicating requirements across multiple disparate user bases, as seen in enterprise programs of record, will not bog down the program.

In this scenario, each small unit would be responsible for their outcomes, including their P&L, paralleling the corporate strategies that drive (and have been successful at finding) innovation. It also concludes that becoming a program of record (POR) may not be the benchmark of success we have thought it to be. SIMNET operated successfully for 10 years before becoming a POR, which may have contributed to its success in originating distributed simulation. Especially for organizations focused on innovation or integration of disruptive technology, anticipating the commercial technology that will be available more than five years in the future is more luck than skill. Typically, when an effort becomes a formal POR, organizations representing the sponsor, developer, and user become decision-making centers. These organizations are often geographically distributed across the United States, trying to build a capability for warfighters overseas, which violates the co-location principle of Agile management. Reflection and fine-tuning become more formal and less frequent, making it more challenging to adapt to changing requirements, timelines, and budgets.

The requirement – a formalized description of the capability, associated specifications, and parameters – drives the development in traditional acquisition models. Though the requirements for any given project may have originated with an operational challenge or problem statement, that statement is relegated to "background information," and the requirements, as written in a single snapshot in time, reign through the entire acquisition lifecycle. The desire to integrate the latest and greatest available COTS technologies, at whatever level of performance specification they are today, is at odds with an acquisition model that freezes requirement specifications to develop toward them, which may be obsolete before they are even approved, which results in the delivery of new systems with outdated capabilities and increasing frustrations by the user community.

Instead, successful COTS integration requires a different development model, which keeps the problem statement in the forefront, with program managers empowered to procure technology that improves the users' position in overcoming that problem, regardless of its current performance specification. The PM and stakeholders can then view alternatives regarding how modern they are, how risky they are, how relevant they are, and how they interact with other solutions in the architecture. In this way, and for problem sets that may apply commoditized technology, PMs let the commercial sector provide the development to fuel a CI/CD pipeline to incrementally improve the degree to which we address a problem set, which allows us to deliver an 80% solution now, AND the 100% solution later.

CONCLUSION

We discussed the power of COTS technology integration into program baselines and transforming the iron triangle of legacy acquisition approaches into an elastic sphere. We explained how Agile program management and acquisition approaches fit within the COTS integration paradigm, and how much more applicable that will become as IT becomes more commoditized in areas other than computational hardware and software. Finally, we provided recommendations on how we might tweak organizational models to drive innovation and function with agility. But what does all this mean to the *program manager* charged with accomplishing these goals?

Leveraging industry investments in commercial technologies to advance government- and DoD-centric capability sets requires reexamining the trade-space between value (performance), cost, and schedule. To maximize the benefits of existing and emerging COTS technologies, PMs should entertain the idea of immediate integration into their technical baselines in an experimentation / TESTDEV environment, rather than conducting months of costly analysis and requirements decomposition to determine if that technology is a right fit. A value-centric mindset is a hallmark of Agile development, resulting in a rapid advancement to an MVP and additional value-added iterations while keeping the problem statement in the foreground. Successful deployment, failure, or subsequent pivot, may face each iteration. Willingness to "fail fast" does not commonly exist in acquisition environments. While PMs are graded on traditional acquisition milestone decisions, failing fast significantly reduces investments in what ultimately is obsolescence.

In current acquisition models, program managers are, for example, measured on the number of requirements met per time unit, the number of test events accomplished, or milestone decisions achieved. Their ability to achieve initial operational capability (IOC) and full operational capability (FOC) according to those static requirements written so long ago, while the pace of change in the information technology landscape is ever-increasing, is another persistent measure of performance. These traditional measurements, therefore, become as irrelevant as the solutions developed under the standard acquisition model. So how, then, should we measure success? If we break down the iron triangle and adopt a more Agile approach, we need to change the way we measure success simultaneously.

Industry measures success by revenue gained and margins achieved. Governmental organizations are not motivated by profits, so we need to look at underlying metrics that drive revenue to mirror industry practices. Throughput (number of users/subscribers serviced per time unit), or number of valuable features (those tied to the problem statement) delivered per time unit, are standard performance measures for IT-centric programs. Alternatively, IT projects with training use cases may be measured on reductions in time to produce trained individuals or cohorts (reduction in training time) or by the quality of the outcome (competency achieved) per time unit. The proposed metrics point to a single common denominator – *utility* – in contrast to legacy systems acquisition models, which measure progress against a linear model for problem statements that may no longer exist and solution sets that are no longer complete/relevant, ex post facto.

PMs would then need to rethink relationships formed with lead systems integrators and rethink acquisition paradigms and associated metrics. Lead integrators and program office-side engineering service providers would need to have a deep understanding of both customer mission and global industry trends and offerings. This balance between operational needs (and associated constraints and limitations) and relevant technical domain expertise will yield a level of trust required to perform in a "fail fast" environment. The lead integrator will bring additional value by curating and leveraging an innovation ecosystem of small businesses, commercial providers, researchers, academia, and other sources of innovation and thought-leadership. That trust, combined with innovation ecosystems, allows for prudent risk management and the ability to deliver solutions in operationally *and* technically relevant timelines.

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