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The Use of COTS in Defense Acquisition Programs: A Research Synthesis and Framework

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Abstract

The DoD faces pressure to sustain its competitive advantages in national security. Enduring budget pressures, a record-long high operations tempo, the blitzing pace of technology, and adversaries that are leveraging commercial technology compound the challenge. The adoption of COTS products into defense acquisitions has been offered to help meet these challenges. A literature review of 62 sources was conducted with the objectives of better understanding COTS product implementation performance. It explored (1) characteristics of the research, (2) policies, laws, regulations, and directives that govern the use of COTS, (3) the known barriers to COTS implementations, (4) the known success factors to COTS implementations, (5) the recommendations have previously been made with respect to COTS implementations, and (6) recommendations for more timely and more effective COTS implementations. From the literature emerged a framework of COTS product usage and a scale to measure COTS product appropriateness that should help to guide COTS product adoption decisions and to help manage COTS product implementations ex post.

Introduction

The United States positions itself as the global leader in national defense, power projection, and the defense of its allies. To attain that vision, the U.S. must stay on the leading edge of technology; that is, it must maintain a competitive advantage in each domain—land, sea, air, space, and cyberspace. However, the U.S. Department of Defense (DoD) is not unbound by its resources. There are ceilings on the number of ships, soldiers, sailors, airmen, and fighter squadrons—to name a few. And the annual allocation of dollars—the ability to acquire resources—is constrained. The provisions of the Budget Control Act of 2011 linger as a reminder of the exploded national deficit, the need for a balanced budget, and sequestration. The estimated budget deficit for fiscal year (FY) 2017 is $577 billion (Amadeo, 2017), while the cumulative national debt is $19.968 trillion, or $61,554 per citizen (USDebtClock.org, 2017).

According to the GAO (2017),

> the Department of Defense faces five key challenges that significantly affect the department's ability to accomplish its mission. These include the need to (1) rebalance forces and rebuild readiness; (2) mitigate threats to cyberspace and expand cyber capabilities; (3) control the escalating costs of programs, such as certain weapon systems acquisitions and military health care, and better manage its finances; (4) strategically manage its human capital; and (5) achieve greater efficiencies in defense business operations. (p. 8)

These challenges are not expected to wane any time soon. Hence, the DoD must continue to innovate in a way other than just technology and weapons—it must figure out how to do even more with less.

Notwithstanding, technology is advancing at a breakneck pace. New developments in autonomous units, light-bending hyper stealth, electromagnetic rail guns, hypersonic missiles, 3D printing, artificial intelligence, big data, lasers, and social media—to name a few—cost money to develop and to harness. Hence, it is very expensive to remain on the leading edge versus current and potential adversaries and against different types of adversaries—conventional and asymmetric. Coupled with the demand on funds is the demand for faster response time. Yet time is no friend to a defense acquisition system that consumes, on average, 8.25 years to field a system from program initiation to initial operating capability (Riposo et al., 2014). Drastic change is needed in the DoD (Garber et al., 2011).

Additionally, adversaries and potential adversaries have expanded into unconventional domains posing threats via space and cyberspace. Even adversaries such as ISIS and Hezbollah have figured out the benefits of commercial technology and have adopted them (Hambling, 2017). They have also expanded into some of the most complicated domains by leveraging commercial technology. This is not surprising since many developments no longer originate in government-owned or contracted laboratories. Rapidly advancing commercial capabilities are deteriorating the United States' advantage (Tucker, 2017).

The use of commercial off-the-shelf (COTS) products is one strategy to help the DoD overcome its challenges. The implementation of COTS products offers faster development time, reduced cost, and higher quality compared to custom development (Torchiano et al., 2002). Yet in some settings, actually achieving those desired outcomes has been fleeting. COTS usage is no panacea (Carney & Oberndorf, n.d.), and is fraught with complexity, difficulty, and risk. According to Ben FitzGerald, a senior fellow at the Center for a New American Security, the DoD consistently struggles with the insertion of commercial technology (Erwin, 2016). Based on a review of approximately 40 programs, defense acquisitions continue to be plagued by immature architectures, COTS integration, interoperability, and obsolescence (Baldwin, 2007).

While some attention was afforded buying commercial items as far back as five decades, the brunt of the thrust occurred in the mid-1990s with the Perry Memorandum and the Federal Acquisition Streamlining Act of 1994. Pockets of success implementing COTS products exist, as do spectacular failures. With greater attention recently on the budget resulting from the Budget Control Act of 2011, coupled with the realization of that the pace of technology is accelerating and that adversaries are leveraging commercial technology, there has been recent renewed attention on accelerating the infusion of COTS products into defense acquisition.

Though the use of COTS products has been widely researched, as apparent from the DoD's struggles to harness it, COTS product usage is not completely understood. The literature on the use of COTS across various contexts is fragmented. There are some DoD-specific case studies of COTS product usage and numerous non-DoD studies—albeit mostly concentrated in the COTS software realm. It has been 17 years since the last comprehensive synthesis of COTS implementations—then conducted by the Air Force Scientific Advisory Board (Grant, 2000). There is no known comprehensive synthesis of COTS usage research.

Scope and Objectives

The purpose of this research, therefore, is to review the literature surrounding the use of COTS technology to better understand COTS product implementation performance. Such a research synthesis seeks to bring together previously disparate streams of work (Webster & Watson, 2002), namely DoD system acquisition, software engineering, supply chain management, marketing (new product development), and knowledge management. The scope of this review includes hardware and software. The following research questions will be explored:

1. What are the known barriers to COTS implementations?
2. What are the known success factors to COTS implementations?
3. What policies, laws, regulations, and directives govern the use of COTS?
4. What recommendations have been made with respect to COTS implementations?
5. What are the typical research types, contexts, research methods, target markets, and foundational theories utilized in COTS-based research?
6. What is recommended for more timely and more effective COTS implementations?

The answers to these six questions are crucial; they should help reduce program risks of poor performance, failure, cost growth, and schedule slippage. The gained knowledge should also help the DoD acquisition community to more effectively and more efficiently leverage COTS products in order to meet its mission mandates and retain a competitive advantage against existing and potential foes.

The remainder of this paper is organized in the following manner. First, the study presents the review methodology. Following the synthesis of the literature, results are then presented. Lastly, discussion, limitations, implications, future research directions, and conclusions are offered.

Methodology

To address the research questions, this research employed a literature review,

> the selection of available documents (both published and unpublished) on the topic, which contain information, ideas, data and evidence written from a particular standpoint to fulfil (sic) certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed. (Hart, 1998, p. 13)

The process for a systematic literature review outlined by Tranfield et al. (2003) was followed. This process consists of three stages: planning the review, conducting the review, and reporting and dissemination. In the planning stage, the need for the review is identified and a review protocol is developed. In stage two, the relevant literature is searched, identified, and selected. Additionally, particular data is extracted and synthesized. In the final stage, a report is drafted that includes recommendations. It is then disseminated.

There exists a mountain of information surrounding the implementation of COTS technologies. A simple Google search of "commercial off-the-shelf" yielded 512,000 hits. Academic databases searched included ProQuest ABI/Inform Global, LexisNexis Academic, JSTOR, and EBSCOHost. Publications by the Acquisition Research Program (ARP) were reviewed. GAO reports were found on the GAO's website. Regulations were found from the Navy's repository found at: https://doni.daps.dla.mil/default.aspx; 1,140 regulations were scanned for COTS applicability. Academic courseware was obtained from the Defense Acquisition University (DAU). Sources were also traced backward from reference lists (Leedy and Ormrod, 2005). Sources searched included peer-reviewed journals, conference proceedings, Acquisition Research Program reports, case studies, GAO reports, DoD reports, search engine (Google and Google Scholar), DAU Acquisition Community Connection, GAO bid protests (on the basis of COTS), U.S. Court of Federal Claims bid protests (on the basis of COTS), books, trade press, white papers, guidebooks/handbooks, patents, and conferences/practitioner organizations.

The massive number of sources found was narrowed by inclusion and exclusion criteria (Table 1). The scope of the knowledge base was expanded beyond the DoD context since there is very little rigorous, peer-reviewed academic research examining only DoD acquisitions involving the use of COTS products. However, the exemplar case studies and the summary of prior recommendations were constrained to DoD COTS product implementations. The literature search terminated when no new viewpoints emerged (Leedy & Ormrod, 2005).

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Defense acquisition context	COTS case studies published prior to 2000
Hardware	COTS implementations by non-U.S. entities
Software	COTS usage in scientific discovery in which COTS product usage is not the study's focus
Studies of for-profit sector COTS usage	Classified COTS product implementations/programs

Once the literature was accumulated, the data extraction form was used to construct concept matrices of barriers and success factors (Webster & Watson, 2002). These tabulations depict the most prevalent antecedents to COTS implementation performance—the key dependent variable in the emerged framework. Looking across sources, patterns and themes were sought (Webster & Watson, 2002). A pattern was considered to exist when a concept appeared in four or more sources as barriers and as enablers (i.e., success factors).

Each article was categorized according to its theory type using Gregor's (2006) typology. Gregor classified information systems theories according to their four objectives: analyzing, explaining, predicting, and prescribing. The resultant typology included five types: analyzing, explaining, predicting, explaining and predicting, and design and action. Analyzing theories simply describes *what is.* They sometimes take the form of classifications or taxonomies. The analyzing theory makes no causal inferences or predictions. Explaining theories do just that; they explain how, what, why, when, and where. Yet, the explaining theories do not posit testable hypotheses. Conceptual models and theory development fit this type. Many case studies fit this classification. Predicting theory says *what is* and *what will be* in the future. While the theory makes predictions and includes testable hypotheses, it does not very well explain why the hypotheses should be (or are) so. In contrast, explaining and predicting theories make predictions, offer testable hypotheses, and explain the causality. Finally, design and action theories explicate *how to* do something. They are prescriptive in nature.

Then, each article was classified by its stage in the knowledge management process per the framework of Beesley and Cooper (2008). Process stages include knowledge creation, dissemination, knowledge transfer, knowledge adoption, and innovation.

To assess the quality of each article, several methodological aspects were evaluated for academic rigor. In Appendix A, this assessment appears in the column labeled Scholarly Academic Evidence. Each article is coded as yes (Y) or no (N). Yes indicates that the article was published in a peer-reviewed source, provides sufficient evidence of validity and reliability, explains type of data, data source, and data collection method with confidence that error is mitigated, and describes an appropriate data analysis method. Otherwise, the article was coded no.

Results

Emerged Constructs and Relationships

From the literature, concepts were coded as individual barriers and enablers to COTS product usage. For the barriers, 86 concepts were identified. For the enablers, 89 concepts were identified. Looking across concepts for commonality and repetition, themes rose to the surface. The central theme seemed to address the fitness of COTS products to the situation, henceforth termed *COTS appropriateness*. The following discussion will explain COTS appropriateness and each of its antecedent factors. See Figure 1 for a depiction of the comprehensive COTS product usage framework.

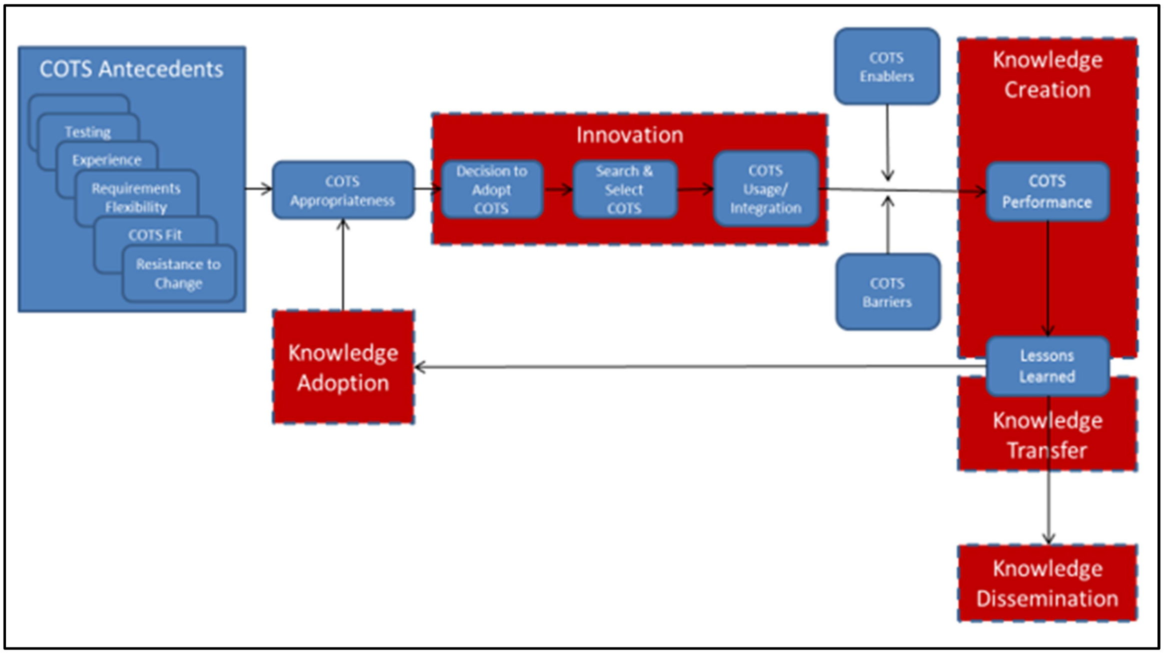

Figure 1. COTS Product Usage Framework

COTS Appropriateness

COTS appropriateness is the focal construct in the emerged COTS framework. Grant (2000) concluded, "Not enough emphasis has been placed on understanding and implementing the process to determine the applicability (that is, the appropriateness) of COTS" (p. 31). The DoDIG (2006a) mentions the inappropriateness of COTS implementation on numerous occasions by the Air Force, then links the inappropriateness to performance failures (e.g., excess costs). Academicians have also taken notice of the importance of COTS appropriateness. Jilani (2008) mentions the selection of inappropriate COTS components. Keil and Tiwana (2005) also mention the disastrous ramifications of selecting inappropriate COTS software. Couts and Gerdes (2010) question the appropriateness of COTS to meet the needs of some integrations. Cechich and Piattini (2007) offer a procedure for detecting the suitability of COTS candidates.

COTS appropriateness is herein defined as the extent to which a COTS product—adopted for use as-is or integrated into another product or system—can meet the program objectives with very little or no modification without introducing excess risk to cost, schedule, performance, safety, or security. It considers the fit between the COTS product functionality and that desired by the DoD user for a particular intended mission effect.

In order to assist researchers studying COTS implementations and to assist practitioners in assessing COTS usage opportunities, a scale is developed to measure COTS appropriateness (See full Technical Report.). This scale is intended to assess the degree of appropriateness, measured on an interval scale of 1 to 7, as determined by the presence (or absence) of the following antecedent conditions.

Antecedents to COTS Appropriateness

Certain situations lend themselves to COTS product usage while others do the opposite. From the DoD case studies and the at-large literature, the following attributes (i.e., factors) determine, at least partially, whether a COTS product should be adopted. These antecedent factors are listed in order of expected strength of the relationship, with the strongest predictors listed first. The Technical Report elaborates on rationales for inclusion with citations from the supporting literature.

RQ1: What are the known barriers to COTS implementations?

There are several antecedent factors that decrease COTS product use appropriateness, as discussed above. These factors, once a COTS product is adopted and as implementation is attempted, reappear as barriers to success. They include a "black box" design, organizational resistance to change, intellectual property constraints, short product life cycles, and complexity.

DoD Examples of Barriers to COTS Implementations

The following 15 DoD programs exemplify barriers to COTS product usage for various reasons. Each program is followed by a citation enabling the reader to trace back the details. As mentioned previously, there is substantial variance in the rigor and details provided for each case.

- Navy Littoral Combat Ship (DoD, 2009)
- USMC Presidential Helicopter Replacement (VH-71) (DoD, 2009)
- Army Armed Reconnaissance Helicopter (ARH) (DoD, 2009)
- Air Force F-22 (Grant, 2000)
- Air Force Depot Maintenance Management Information System (Grant, 2000)
- Air Force Expeditionary Combat Support System (ECSS) (Charette, 2013)
- Air Force KC-767A Tanker Lease (DoDIG, 2006a; DoDIG, 2004a; GAO, 2006)
- Air Force C-130J (DoDIG, 2006a; DoDIG, 2004b)
- Air Force and Navy T-6A Texan II, Joint Primary Aircraft Training System (JPATS) (DoDIG, 2006b)
- Air Force Wideband Gapfiller Satellites (DoDIG, 2006a)
- Navy and Air Force MV/CV-22 Osprey engines (DoDIG, 2006a)
- Air Force C-17A engines (DoDIG, 2006a)
- Army High Mobility Multipurpose Wheeled Vehicle (HMMWV) (DoDIG, 2006a)
- Air Force T-3 Firefly (Baker, 2002)
- Army DCGS-A (Brill, 2017)

RQ2: What are the known success factors to COTS implementations?

There are several antecedent factors that increase COTS product use appropriateness, as previously discussed above. These factors, once a COTS product is adopted and as implementation is initiated, reappear as enablers to success. They include the fit between requirements and COTS product capabilities, requirements flexibility, COTS product experience, open systems architecture, a robust COTS product evaluation and selection process, post-adoption COTS product change preparedness, COTS product training, communication, evaluating total cost of ownership, a priori and post hoc testing, marketplace knowledge, leadership, stakeholder buy-in, and contractual financial incentives.

DoD Examples of Effective COTS Implementations

The following 23 DoD programs exemplify enablers of COTS product usage. Like the aforementioned barriers, each program is followed by a citation enabling the reader to trace back the details.

- DoD Common Access Card (GlobalPlatform, 2003)
- Air Force Manufacturing Resources Planning (MRP) (Grant, 2000)
- Advanced Amphibious Assault Vehicle (AAAV) (Grant, 2000)
- New Attack Submarine and Acoustic Rapid COTS Insertion (ARC-I) (DoD, 2009; Grant, 2000; Boudreau, 2006; Ford & Dillard, 2009)
- Navy Sea Fighter (FSF-1) (DoD, 2009)
- Airborne Warning and Control System (AWACS) (Grant, 2000)
- Navy E-2 Hawkeye Early Warning Program (Gansler & Lucyshyn, 2008)
- Army Light Utility Helicopter (Gansler & Lucyshyn, 2008)
- DLA Business System Modernization (BSM) (Gansler & Lucyshyn, 2008)
- Army's General Fund Enterprise Business System (GFEBS) (Kendall, 2015)
- Lightweight Autonomous Underwater Vehicles (AUVs) (Incze, 2011)
- Navy P-8 Poseidon maritime patrol and reconnaissance aircraft (DoD, 2009; Naegle & Petross, 2010)
- Air Force C-5 Reliability Enhancement and Re-Engining Program (RERP) (Lorell et al., 2017)
- Air Force and Navy Joint Direct Attack Munition (JDAM) (Grant, 2000; Lorell et al., 2017)
- Air Force Small Diameter Bomb (SDB I) (Lorell et al., 2017)
- Air Force Wideband Global SATCOM (WGS) System (Lorell et al., 2017)
- Mine Resistant Ambush Protected (MRAP) vehicles (Morrow, 2010)
- Army M-ATV (Morrow, 2010)
- Aegis Ballistic Missile Defense System (Lockheed-Martin, 2017)
- Defense Healthcare Management Systems Modernization (DHMSM) (DoDIG, 2016b; Landi et al., 2017)
- Army's Single Stock Fund (SSF) program (Alcide, 2006)
- USMC utility task vehicle (UTV) program (Tadjdeh, 2017)
- Army Ka-Band Satellite Transmit and Receive System, AN-GSC-70(V) (Stein, 2006)

RQ3: What policies, laws, regulations, and directives govern the use of COTS?

Most of the attention to buying commercial items occurred in the mid-1990s with the Perry Memorandum and the Federal Acquisition Streamlining Act of 1994. There has been recent renewed activity in the amount of COTS-related law, policy, regulation, and directives. The Technical Report lists the relevant laws, policies, regulations, and directives.

RQ4: What recommendations have been made with respect to COTS implementations?

Over the years, several oversight authorities and researchers have made recommendations for practitioners in order to improve their management of COTS product implementations. A list of those recommendations is provided in the Technical Report.

RQ5: What are the typical research types, contexts, research methods, target markets, and foundational theories utilized in COTS-based research?

The Technical Report shows the data collection methods and data analysis methods employed. It lists the publications from which COTS product usage literature was found. The report also shows the types of research and the process steps of Beesley and Cooper's (2008) knowledge management framework in which each reviewed article fits.

Discussion

Managerial Implications

COTS product implementation is complex and difficult to successfully navigate. This is evident in simply the number of antecedent factors that affect COTS usage appropriateness that emerged from the literature. Additionally, some additional factors are likely to be significant actors, yet may not have risen to the top as a pattern due to the limited number of published case studies.

While there appears to be a desire to use COTS products (evidenced by statutory requirements and policy directives), the actual integration of COTS products into systems is easier said than done. It introduces one more risk to programs that is unlikely to be welcomed by program managers who spend their days anticipating and defending against risks. What has the DoD structurally infused to alleviate those perceived risks from program managers? The emerged framework, based on findings from academic studies and case studies of DoD COTS product implementations—coupled with knowledge management literature—clearly indicate the importance of monitoring the commercial marketplace. An organization must possess the ability to recognize the value of new external information (Grandinetti, 2016). In order to recognize the value, marketplace observers must know the technical and scientific details, know the DoD's existing infrastructure, and be familiar with user needs and desired effects. This not a novel idea; market intelligence cells were recommended in 2014 (Finkenstadt et al., 2014). The number of available organic personnel with these skills, experience, and education—that is, with the requisite knowledge—is scant. Thus, it is likely that, without intervention, the DoD will continue to rely on systems integrators to conduct the commercial marketplace monitoring. This outsourcing of sorts raises serious implications of agency theory. In whose interest is the monitor working, and how is knowledge transformation (aka, assimilation or transfer) being manipulated or withheld? Since the ability to take on new knowledge to some extent depends on the amount and type of knowledge already possessed, how is the integrator's knowledge being managed such that it is not lost?

Commercial off the shelf, as a topic, appears to be waning since the 2005–2009 timeframe. The quantity of source hits resulting from the search term "commercial off the shelf" in the ProQuest ABI/Inform Global database has modestly decreased recently. The quantities of hits are distinguished between peer-reviewed journals (PRJ) and all COTS-related articles. This decrease has not gone unnoticed (Maras et al., 2012). This trend is somewhat corroborated by examining the number of patents (Google, 2017) using the term commercial off the shelf. The quantity of COTS-related patents also seems to have peaked and is now waning. These trends could suggest that the practice of using COTS products is in decline, or it could simply mean that labeling COTS usages as such may be in retreat as the practices become rather standard (Maras et al., 2012). This reduction would be expected as the usage of COTS becomes ubiquitous; thus, perhaps authors perceive the term *COTS* to be implied and therefore, unnecessary to mention.

"There is a failure to assure correct, predictable, safe, secure execution of complex software in distributed environments" (Baldwin, 2007, p. 8). Research does not address the issue of security involved with adopting COTS products (Grant, 2000). The new DFARS clause 252.204.7012 requiring the protection of defense information and cyber incident reporting applies to systems that integrate COTS, but not to purely purchased commercial items (Cassidy & Stanton, 2017). Included within the realm of security is counterfeiting. Very little research addresses counterfeiting though it clearly poses a risk to system performance and to security. Supply chain risks with respect to IT may include insertion of counterfeits, unauthorized production, tampering, theft, insertion of malicious software and hardware, and poor manufacturing and development practices (Gump et al., 2015); thus, grey market products—those distributed beyond the manufacturer's intended channel—should be avoided. But gaining control of a free-market supply chain is daunting, as indicated by the Aerospace Industry Association's concern over recent DFARS changes (AIA, 2014). The security of COTS-based systems is and will continue to be a serious issue (DoDIG, 2016a). And the DFARS requirements for counterfeit electronic part detection and avoidance (DFARS 252.246-7007) that flow down to suppliers might repel viable COTS product sources.

Research hardly addressed the issue of intellectual property (IP) involved with adopting COTS products (Grant, 2000). However, the literature since 2000 suggests that intellectual property rights is a formidable barrier. This is logical particularly in systems that have to reconcile the IP rights of multiple pieces of hardware or multiple software components. One component repository, ComponentSource, currently makes available 1,933 components, 705 applications, and 384 add-ins to systems integrators and developers available from 343 publishers (ComponentSource, 2017). Imagine keeping track of the use restrictions, access rights, royalties, warranties, and liabilities of only 10 components. Then imagine that each of those sets of 10 terms and conditions is different.

Commercial firms rapidly update their products to keep pace with technology and in the pursuit of new avenues of differentiation and, thereby, competitive advantage. Short product life cycles and short time-to-market make design and acquisition time critical. Experimentations of new ways to quickly access new commercial technology will be important. One example is the DoD's pilot program called Commercial Solutions Opening (CSO) established by Section 879 of the National Defense Authorization Act (NDAA) for FY 2017 (Public Law 114-328) and implemented by DFARS Case 2017-D029. A CSO is a merit-based source selection strategy that utilizes Other Transaction Agreements (OTA) rather than contracts pursuant to the FAR. Under the Defense Innovation Unit Experimental (DIUx) program (https://diux.mil/), 25 OTAs have been awarded valued at $48.4 million (Defense Innovation Unit Experimental [DIUx], 2017). This program is drawing private investment from venture capitalists and participation from firms that normally do not transact with the DoD. Recent initiatives include autonomy, personal aerial vehicle, tactical autonomous indoor drone expansion, human cooling, digitally aided close air support platform, hardened network defense, knowledge management, multifactor authentication for network access, and advanced analytics from synthetic aperture radar imagery.

While COTS software has been researched extensively, COTS hardware receives very little scholarly attention. This could be attributed to the newness and magnitude of software issues. It could also be due to the expectation that the commercial sector will favor commercial hardware integration when it is cost effective.

From the literature, user satisfaction is a key measure of information systems COTS success (Kakar, 2013); however, user satisfaction did not appear from the DoD case studies as a key to successful COTS implementation. This could be attributed to a top-down paradigm that the user gets what the program office delivers. Hence, while system performance defines success, the literature shows ambivalence toward the user's perception. Nevertheless, the ubiquitous technology acceptance model (Davis, 1989) shows that IT system adoption is driven by perceived ease of use and by perceived usefulness.

The DoD struggles to use COTS products to create a military advantage (Erwin, 2016). Clearly, some commercial products are not designed and built to meet the rugged needs of military applications. Nonetheless, the DoD's struggle is perhaps most brightly illuminated by the Palantir case—a commercial analytics product which soldiers have lauded as life critical but which was refused by the Army somewhat arbitrarily (U.S. Court of Federal Claims, 2016). Thus, antecedent factors for COTS product adoption beyond functional capability deserve special attention.

The relevant literatures surrounding COTS implementations is severely lacking in theoretical grounding (Hall & Rapanotti, 2016). This void can stymie understanding and the pace of progress. Other business-oriented, applied disciplines have also struggled to find unique theoretical foundations explaining and predicting their phenomena, such as supply chain management (Defee et al., 2010) and information systems (Gregor, 2006). Few studies dig into causal relationships explaining or predicting phenomena. Yet, such studies yield the strongest evidence answering why things are the way they are and how things might be expected to be in the future. Hence, explaining and predicting is the essence of theory and discovery. Since knowledge is cumulative (Cohen & Levinthal, 1990), more research attention should explore causal relationships.

Few case studies of COTS product usage would qualify as scholarly contributions. Thus, it is difficult to discern between truth and conjecture, or more likely, to get beyond the visible symptoms and discover the underlying causes. Therefore, consumers of information in many of the existing case studies may be forming beliefs and making decisions based on anecdotal evidence and hasty conclusions. Most "case studies" lack methodological rigor and sufficient detail explaining how findings were determined, what type of data was collected, how data was collected, how data was analyzed, and how validity and reliability were assured. Very few case studies involving interviews mentioned the location of interviews or whether they were conducted face-to-face, over the phone, or online. Few cases mentioned recording the interviews, transcribing them, interview durations, transcript lengths, and sending transcripts to informants for validity. Few cases summarized the demographics of who was interviewed such as duty title, industry, organization, years of experience, nationality, location, etc. Likewise, few case studies mentioned triangulating data with other sources (e.g., archival records—how many and what type) to corroborate data and analyses. Few case studies mentioned the qualitative data analysis methodology such as coding qualitative text, seeking themes, the number of themes identified, identifying patterns, and unveiling associations among themes via constant comparison—a process of continuously returning back to all text once a new theme or pattern emerged and via code matrices (Miles & Huberman, 1994). Few case studies offered any information about validity and reliability such as using multiple coders of themes and measuring inter-rater reliability and conducting member checking sessions (Yin, 2009) to validate findings and analyses. Few cases reconciled the findings with the relevant literature as evidence of further validity.

Some have called for a new defense acquisition process tailored to COTS product usage. The literature reviewed herein, while offering a substantial number of considerations when adopting COTS products, does not compellingly suggest that the DoD's 5000 series cannot effectively integrate COTS products. Perhaps some changes could be made to provide guidance and consistency to the field to account for some of the nuances and complications of COTS product adoption. Horowitz and Lambert (2006) offer some insight:

> An assembly sequence (components to be assembled, corresponding dates and costs) has several risks including: 1) technical risk: successful (or not) function of assembled components by planned schedule milestones; 2) operational risk: achieving (or not) the desired business value by using the new system of assembled components; and 3) programmatic (schedule and cost) risks: accomplishing the assembly within time and budget constraints. (p. 286)

They thus presented a framework (called "learn as you go") for planning and adjusting milestone sequences in assembling off-the-shelf software components. Principles from this framework could be borrowed to tweak, or allow for special cases within, the DoD 5000 series of directives and instructions.

RQ6: What is recommended for more timely and more effective COTS implementations?

1. Apply the proposed COTS Product Appropriateness scale (see Technical Report) to prospective programs when contemplating integrating major COTS components. This scale captures the emerged antecedent factors (from barriers and enablers), and therefore, should serve as a helpful indicator of the prospect.
2. To facilitate knowledge management, DoD activities should record COTS product implementations in contract action reports. This will enable future program managers, technical authorities, and contract managers a single, reliable source from which to search for prior COTS implementations by similarity of COTS technology type (e.g., software components, avionics, land-based robots, etc.). This knowledge can rapidly inform decision-makers of where to go to gather additional detailed information on lessons learned, market research, and suppliers to facilitate knowledge dissemination.
3. Expounding on the previous recommendation, COTS product implementations should be catalogued in a central repository in order to make detailed lessons learned available to future acquisition teams. Since no single, optimal solution to knowledge management can be developed (Bjornson & Dingsoyr, 2008), this central repository could complement other knowledge management practices. For example, the deposited lessons learned could be pushed to educators and trainers at DAU, NPS, AFIT, ICAF, senior service shools, and interested university centers.
4. Since tacit knowledge resides with people, organizations should set, via policy, maximum program employee turnover rates. Turnover has repeatedly been found a culprit in failed and low performing programs (Charette, 2013).

5. Over the years, several oversight authorities and researchers have made recommendations for practitioners in order to improve their management of COTS product implementations such that desired, and in some cases mandated, outcomes are achieved. However, the extent to which all of these recommendations have been implemented is unknown. Therefore, an audit of the recommendations would be useful to reconcile the deficiencies and weaknesses of current practice with required and helpful practices (i.e., the recommendations). The audit results would provide a gauge of the extent that current processes and policies are sufficient and that COTS product usage is sufficiently managed.
6. It appears that, in the realm of software, the use of COTS products is such a pervasive commercial practice that products involving software nearly cannot be developed without at least some integration of COTS products. This is undoubtledly due to the significant savings in costs and time. Nevertheless, what is not as ubiquitous is the extent of reuse of physical COTS products (i.e., hardware). Thus, a study should be conducted to quantify the extent of COTS implementation, and quantitatively validate the positive and negative antecedents to COTS implementation performance.
7. The DoD should not establish quotas for COTS implementations. Quotas have, in the past, manifested in percentage goals (i.e., COTS products have to constitute a certain percentage of a system). Extrinsic forcing mechanisms could result in gaming and unnecessary risk-taking.
8. Set policy that requires a technical evaluation sub-factor in all source selections that: (1) requires offerors to submit their plan for making their deliverables (including components of them) open to competition during sustainment, and (2) allows for meaningful evaluation credit (i.e., ratings, strengths, and reduced risk ratings) for superior plans. These plans, in turn, should become part of the resultant contract.
9. In contracts involving award fees, consider making the extent of COTS implementation one of the criterion for award fee determination.
10. For all contracts requiring the use of COTS products, add an assessment of: (1) the extent of COTS product usage and (2) COTS product implementation effectiveness to the contractor performance assessment reporting (CPAR). This follows recommendations by Rendon (2007). It should motivate contractors to pursue the integration of COTS products since many suppliers place significant attention on achieving desired CPAR scores (Hawkins, 2016).
11. Expand the scope of the DoD's Strategic Capabilities Office (CSO) organized as a Janus-facing orgnization around desired effects and simultaneously around commercial industries. Within the CSO, technology expert councils (i.e., industry-facing organization) would need to matrix to the revolutionary effects council (i.e., warfighter-facing organization). A sufficient number of standing councils would be needed to adequately cover the various high-potential industries and the most-impactful effects.
12. The DoD should build structure to facilitate knowledge management and absorptive capacity. This means that resources such as people, time, and technology should be allocated to monitoring the marketplace for commercial products and new technology capabilities. There are pockets of excellence such as the CSO and DIUx; however, their scope and capacity is likely too

small to assist all current and yet-to-be-discovered needs. Those monitoring the marketplace must be technically adept so that they will be able to recognize valuable information when they see it. Additionally, the curb on travel should be lifted for the defense acquisition workforce. If anything, these technical and business professionals need more exposure to commercial knowledge, not less. Conferences are efficient forums to interact with numerous experts in a short amount of time. Finally, discovered knowledge should be codified (i.e., made explicit) and be available to future market monitors since absorptive capacity depends on the amount of knowledge previously acquired.

13. In developing the COTS implementation framework, a scale to measure the focal construct, COTS appropriateness, was developed. This scale, in its current form, should be considered exploratory. Hence, it should be empirically tested to ensure reliability and all types of validity (i.e., content, construct, discriminant, convergent, nomological, and external). Once validated, the scale should be used by practitioners to assist in their decisions whether to adopt COTS products. The scale can also be used by academicians to empricially study COTS implementations.
14. Researchers pursuing COTS-based inquiry should ground their research in relevant theory. Journals and academic conferences publishing COTS-based works should add to their requirements a review of the relevant literature and an explicit positioning of the work into that body of knowledge.
15. Case studies of COTS product usage should demonstrate greater methodological rigor and provide more detail explaining how findings were determined, how data was collected and analyzed, and how validity and reliability were assured. This will prevent the adoption of anecdotal evidence and hasty conclusions. A commonly-adopted method is provided in *Case Study Research: Design and Methods* by R. K. Yin (2009).
16. The DoD should leverage its commercial business internships, such as the Air Force's Education With Industry program and the Navy's Supply Corps Training With Industry program, to glean commercial practices with respect to new product design, development, manufacturing, and sustainment. A specific focus could be placed on gaining knowledge of COTS product insertion and accompanying intellectual property rights. These uniformed officer interns can then return to the DoD to help implement the practices.

Conclusion

This literature review was commissioned with the objectives of better understanding COTS product implementation performance. It explored (1) the typical research types, contexts, research methods, target markets, and foundational theories utilized in COTS-based research, (2) policies, laws, regulations, and directives that govern the use of COTS, (3) the known barriers to COTS implementations, (4) the known success factors to COTS implementations, (5) the recommendations have previously been made with respect to COTS implementations, and (6) recommendations for more timely and more effective COTS implementations. From the literature emerged a framework of COTS product usage that should help to guide COTS product adoption decisions and to help manage COTS product implementations ex post.

These six aspects of COTS product implementations are crucial; they should help reduce program risks of poor performance, failure, cost growth, and schedule slippage. The gained knowledge should also help the DoD acquisition community to more effectively and more efficiently leverage COTS products in order to meet its mission mandates and retain a competitive advantage against existing and potential foes.

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