WKU-AM-17-213

ACQUISITION RESEARCH PROGRAM SPONSORED REPORT SERIES

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

18 September 2017

Timothy G. Hawkins, Ph.D., Lt Col, USAF (Ret)

Western Kentucky University

Disclaimer: This material is based upon work supported by the Naval Postgraduate School Acquisition Research Program under Contract No. N00244-16-1-D0058-0003. The views represented in this report are those of the author and do not reflect the official policy position of the Navy, the Department of Defense, or by the U.S. government.

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

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

To request defense acquisition research, to become a research sponsor, or to print additional copies of reports, please contact any of the staff listed on the Acquisition Research Program website (www.acquisitionresearch.net)

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.

Keywords: Commercial-Off-The-Shelf (COTS), Defense Acquisition, Literature Review

THIS PAGE INTENTIONALLY LEFT BLANK

About the Author

Timothy G. Hawkins, Lt Col, USAF (Ret.), PhD, is an associate professor in the Department of Marketing, Western Kentucky University and a National Contract Management Association Fellow. He researches and teaches in the realms of supply chain management, marketing, government contracting, and strategic sourcing. He has 20 years of sourcing experience in industry and government. Dr. Hawkins has published articles on opportunism in buyer–supplier relationships, source selection, services procurement, performance-based logistics, collaborative pricing, and electronic reverse auctions in scholarly publications such as the *Journal of Supply Chain Management*, *Journal of Business Logistics*, *Journal of Purchasing and Supply Management*, *Journal of Business Research*, *International Journal of Logistics Management*, *Journal of Defense Analytics and Logistics*, *Defense Acquisition Research Journal*, *Industrial Marketing Management*, *Journal of Business Ethics*, *Supply Chain Management: An International Journal*, *Journal of Marketing Channels*, *Air Force Journal of Logistics*, *Journal of Contract Management*, *International Journal of Procurement Management, Journal of Product and Brand Management,* and *Journal of Public Procurement*. His current research interests include procurement ethics, buyer–supplier relationships, strategic sourcing, services procurement, and supplier performance management.

Timothy G. Hawkins, Lt Col (Ret.), USAF, PhD
Department of Marketing
Western Kentucky University
1906 College Heights Blvd, #21059
Bowling Green, KY 42101
Tel: (270) 745-2412
E-mail: timothy.hawkins@wku.edu

THIS PAGE INTENTIONALLY LEFT BLANK

WKU-AM-17-213

ACQUISITION RESEARCH PROGRAM SPONSORED REPORT SERIES

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

18 September 2017

Timothy G. Hawkins, Ph.D., Lt Col, USAF (Ret)

Western Kentucky University

Disclaimer: This material is based upon work supported by the Naval Postgraduate School Acquisition Research Program under Contract No. N00244-16-1-D0058-0003. The views represented in this report are those of the author and do not reflect the official policy position of the Navy, the Department of Defense, or by the U.S. government.

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

List of Figures

THIS PAGE INTENTIONALLY LEFT BLANK

List of Tables

THIS PAGE INTENTIONALLY LEFT BLANK

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 amount 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 (US Debt Clock.org, 2017).

According to the Government Accountability Office (GAO) "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" (GAO, 2017a, 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 and 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).

Weapons systems depend on software. The value of the worldwide software industry was estimated to be $407.3 billion in 2013 (Gartner, 2014). The U.S. software publishing market alone constitutes over half of that - $217.6 billion (IBISWorld, 2017). While the number of contracts for commercial items and services has decreased since 2007, spending on commercial items and services has constituted between 16 and 22 percent of all of DOD's contract spending (GAO, 2017b). The DOD, with its appetite for cloud computing and big data, has recently significantly increased its spending on command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) applications to $39 billion with projections of 1.4 percent annual increases through 2020 (Keller, 2015). Yet, the DOD faces structural problems in the management of weapon system software (Baldwin, 2007).

DOD business processes also depend on software. "The federal government plans to invest more than $89 billion on IT in fiscal year 2017. However, investments in federal IT too often result in failed projects that incur cost overruns and schedule slippages while contributing little to the mission-related outcome" (GAO, 2016, p. 2). "In February 2015, [GAO] introduced a new government-wide high-risk area, Improving the Management of IT Acquisitions and Operations" (GAO, 2016, p.7). "Since the release of GAO's 1995 High Risk report, we have designated the department's business systems modernization program as high risk because of its vulnerability to fraud, waste, abuse, and mismanagement, and because of missed opportunities to achieve greater efficiencies." (GAO, 2015, p.1).

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:

"Increasing the precision of a reliable evidence base in order that policymakers and practitioners can make more sensitive judgements is the ultimate aim of the application of systematic review procedures to management research" (Tranfield et al., 2003, p. 219). The purpose of this research, therefore, is to review the literature surrounding the use of COTS technology to better understand COTS product implementation performance. Burgeoning evidence is convincing that COTS product usage results in faster system deployment, lower development costs, and better performance (Boudreau, 2006; Grant, 2000; Gansler and Lucyshyn, 2008). However, we also know that often times, COTS implementations do just the opposite and even fail. Thus, a contingency perspective is needed to understand what factors either help or hinder the attainment of desired outcomes. Much of this knowledge exists, yet nobody has taken inventory.

Such a research synthesis seeks to bring together previously disparate streams of work (Webster and 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, a literature review is presented describing the underlying theoretical foundations. Next, 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.

THIS PAGE INTENTIONALLY LEFT BLANK

Theoretical Foundations

"Theories are practical because they allow knowledge to be accumulated in a systematic manner and this accumulated knowledge enlightens professional practice" (Gregor, 2006, p.613). Similar to the conclusion of Ashworth et al. (2002), a single comprehensive theoretical framework explaining the use of COTS technologies was not found. Such a complex phenomenon can only be explained by synthesizing aspects of multiple theories such as those found in knowledge management, information systems, program and project management, systems acquisition, systems engineering, innovation and new product development, supply chain management, and buyer-supplier relationships domains – to name a few.

Theory in the realm of software engineering is in a nascent stage of development; yet it is needed to shed light on the discipline's most perplexing problems (Hall and Rapanotti, 2016). Software engineering has been studied through the lens of knowledge management (Hauge et al., 2010). Since most DOD systems entail software and since an information system design project is a multi-phase process of knowledge creation and reuse (Tran, 2012), knowledge management serves as an appropriate theoretical foundation.

Knowledge Management

The context of COTS product usage is economic, that is, product development and improvements for the purpose of satisfying customer demand, creating stakeholder value, and, in some cases, establishing a competitive advantage. These unique instruments of value result from innovation - ''the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services'' (Luecke and Katz, 2003, p. 2). The U.S. economy is a knowledge economy (Beesley and Cooper, 2008); the source of sustainable competitive advantage is the ability of human resources to do three things: generate, disseminate, and use knowledge. We can conclude this based on the unsuccessful overemphasis of the knowledge management field on technologies to capture, store, and help in retrieving information (Bjornson and Dingsoyr, 2008).

Therefore, figuring out how to affect these three processes is the focus of senior leaders.

One oft-cited definition calls knowledge management as "[a] conscious strategy of getting the right knowledge to the right people at the right time and helping people share and put information into action in ways that strive to improve organisational performance" (O'Dell et al., 1998, p. 6). On average, companies that effectively managed their knowledge achieved a 5 percent increase in their return on sales, return on assets, operating income to assets, and operating income to sales (Holsapple & Wu, 2011). Benefits of effective knowledge management include superior knowledge acquisition, superior storage and retrieval, superior sharing and dissemination, and superior decision making (Holsapple & Wu, 2011).

Organizations must understand the difference between tacit and explicit knowledge. Explicit knowledge is articulated in some sort of trade secret, patent, copyright, process, written instructions, or documents (Nissen, 2006). Tacit knowledge, on the other hand, is knowledge specific to an organization and gained through experience (Nissen, 2006). Tacit knowledge is often more powerful than its explicit counterpart (e.g., reading a book about flying an airplane is not the same as experiencing flying), but it is problematic also: it does not flow freely; it is difficult to transfer; it is not easily understood by others; and it is often taken for granted until it is gone (Nissen, 2006). This is the case in particular when tacit knowledge walks out the door in the minds and experiences of seasoned professionals who retire, quit, transfer or otherwise leave an organization's service.

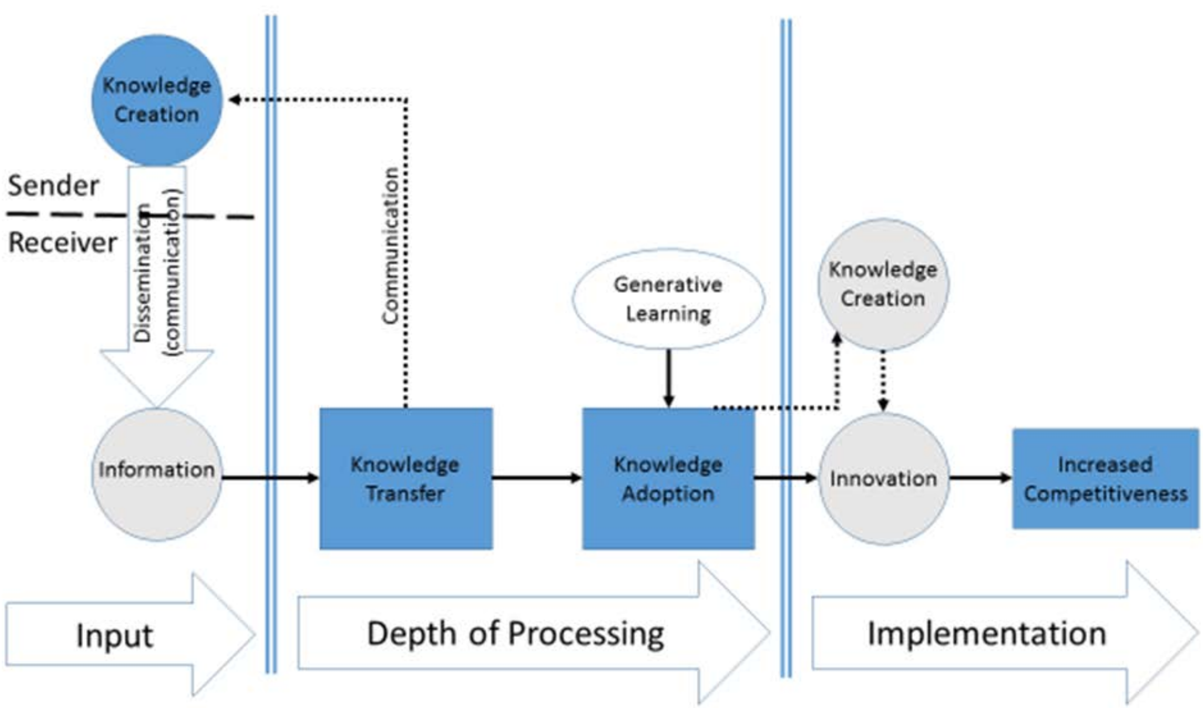
Knowledge flow within an organization, whether tacit or explicit, is only as good as the method that employees within a firm use to start and keep it flowing. Tacit knowledge tends to flow within an organization very slowly, whereas explicit knowledge tends to flow very broadly and quickly. Activity is the key to knowledge flow (Nissen, 2006). Similar to Newton's law of motion, knowledge confined within an individual, or even in an IT system, tends to stay at rest unless there is some sort of activity (e.g., training, mentoring, research, trial and error, discussion) to spark the learning process (Nissen, 2006, p. 34). Activity causes continuous learning, whether it is in the business or academic realm. Although some of this knowledge is not equally distributed (especially across novices and experts), the more knowledge a firm applies through action and performance, the more likely the organization will gain a competitive advantage.

Knowledge management exemplifies a multi-disciplinary approach (Bjornson and Dingsoyr, 2008) to complex real-world phenomena with a focus on relating micro-level decision-making to macro-level outcomes (Ragab and Arisha, 2013; Desouza et al., 2003). "Organizational knowledge is formed through unique patterns of interactions between technologies, techniques, and people…" (Bhatt, 2001). Two main strategies for managing knowledge include codification and personalization (Hansen et al., 1999). Codification entails systematizing and storing information that comprises the firm's knowledge, and making the information available to employees. Personalization involves facilitating the flow of information in a company by centralizing the storage of information about knowledge sources, resembling a directory of who holds which knowledge.

Beesley and Cooper's (2008) widely cited framework underpins this study. The Beesley and Cooper knowledge acquisition and utilization framework (KAUF) synthesizes insights from across several theoretical domains to explain the process that transforms information into knowledge that is acted upon to make a change resulting in improved competitiveness. The center of the model focuses on depth of processing (see Figure 1). The input to the processing stage is the knowledge created or received by a sender that is disseminated through a communication process to a receiver as information. At this point, the information enters the processing start when the receiver enters it into the knowledge transfer process, the product of which undergoes knowledge adoption, possibly guided by generative learning, in order to create an innovation, which can be thought of as an adaptation. The depth of processing depends on the extent that information undergoes knowledge transfer-adoption-learning, with the possibility of new knowledge being created. The knowledge that becomes adopted as the result of the processing and learning becomes implemented as the innovation or change that subsequently results in increased competitiveness. Research from the new product development stream of marketing literature corroborates this linkage. Higher levels of innovativeness are associated with cultures that emphasize learning and development (Hurley and Hult, 1998). By recognizing that knowledge cannot simply be received but begins as information that undergoes stages of input-processing-implementation with various depths of processing, the framework can unify insights from across many commonly used knowledge management theories. This is important since research shows that a major challenge in knowledge management is to facilitate the flow of knowledge between individuals so that the maximum amount of transfer occurs (Bjornson and Dingsoyr, 2008).

The KAUF lies embedded in a contextual greater framework with five factors that interact symbiotically. Knowledge acquisition and utilization lay at the intersection of communication, cognition, and social contingencies, all of which reside in the domain of affect; there is an interplay between affect and values.

Figure 1. Knowledge Acquisition and Utilization Framework (Beesley and Cooper, 2008)



Absorptive Capacity

A theoretical concept with similarities to knowledge management theory, and popular in the supply chain management literature (Grandinetti, 2016), is absorptive capacity (Cohen and Levinthal, 1990). While similar to the knowledge management framework of Beesley and Cooper (2008), absorptive capacity is distinct enough to be considered supplementary since it: (1) offers distinct and important nuances and (2) addresses an organization's ability to acquire and use new knowledge, rather than just the process of managing knowledge. Absorptive capacity theory holds that an organization's ability to innovate depends on the ability of the organization to exploit external knowledge. Absorptive capacity entails four key processes: monitoring, evaluating new knowledge, assimilation, and new knowledge use. It follows, then, that an organization must possess the ability to recognize the value of new external information (Grandinetti, 2016). Zahra and George (2002) developed a four-dimensional construct of absorptive capacity that includes the factors: acquisition, assimilation, transformation, and exploitation. Notably, their concept of transformation requires that new knowledge absorbed be combined with knowledge already possessed within the organization. Hence, an organization's ability to absorb knowledge depends, to an extent, on the amount of knowledge previously acquired. Knowledge is cumulative. Since the implementation of COTS products requires knowledge of the marketplace (i.e., monitoring) and requires the integration of that knowledge into a learning process as to how the knowledge might be exploited to satisfy operational needs, absorptive capacity is an important, relevant aspect of COTS product usage.

Supply Chain Management

In the for-profit sector, the standardization of parts across product offerings has long been a strategy prompted and driven by executive-level strategic supply managers (e.g., Chief Procurement Officers) whose ambition is to reduce total supply chain costs (Peterson et al., 2013). The idea is that managing fewer stock keeping units (SKU) allows the risk pooling of demand; fewer items of inventory can satisfy more demand. The result is lower inventory costs, lower inventory carrying costs, and more efficient production due to longer production runs of the same part (in cases in which the firm makes the component in house) or lower unit prices due to economies of scale via higher purchase quantities (in cases in which the firm purchases the components from suppliers). Less inventory also means the firm does not need as much space for storage (i.e., less warehousing costs). Fewer SKUs also means lower ordering costs from suppliers. Fewer items purchased from suppliers (i.e., less inventory due to risk pooling) also results in lower transportation costs. Thus, what may seem like a simple, small change of reducing a SKU through standardizing parts actually can translate into substantial supply chain savings when scaled across hundreds or thousands of parts, ultimately leading to a lower cost of goods sold, lower sales prices passed along to customers and/or higher profit and, thereby, a competitive advantage.

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). A literature review can be used to: identify what needs to be done distinct from what has previously been done, unveil relevant variables and constructs, synthesize information, identify relationships between variables and constructs, frame the context of a topic or problem, reveal the significance of a problem, decipher any peculiar vocabulary, understand the subject's structure, relate theory to practice, identify the common research methodologies with respect to the subject, and establish the research into a its historical chronology (Hart, 1998). Literature reviews also facilitate the development of new theory and unveils areas in which research is needed (Webster and Watson, 2002).

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.

A systematic literature review begins with the identification of keywords and search terms (Creswell, 2003; Tranfield et al., 2003). Terms are added and evolve as the literature is reviewed. Table 1 lists the search terms and keywords used to find the relevant literature.

This review does not involve the re-analysis of primary data from the reviewed sources. Additionally, specifying and judging quality of qualitative research is difficult (Tranfield et al., 2003). Further, “improving the translation of research evidence into practice is not unproblematic as the relationships between research, knowledge, policy, and practice are always likely to remain loose, shifting and contingent” (Tranfield et al., 2003, p. 219). In an effort to reduce bias and error, a data extraction form was used to capture the features of each source (Appendix A). This form is directly linked to the research questions, records decisions made during the review, and serves as a data repository for analysis (Tranfield et al., 2003). The framework was developed through an aggregative (versus interpretive) approach. The unit of analysis was a published COTS product implementation study.

Table 1. Search Terms and Keywords

Search Terms
Commercial Off-The-Shelf
COTS
Open Architecture
Open Source Software
Component-Based Software Engineering
System Development
Commercial Off-The-Shelf Hardware
Reuse
Case Study
White Paper
Department of Defense

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 DAU. Sources were also traced backward from reference lists (Leedy and Ormrod, 2005). Table 2 lists the various types of sources searched.

Table 2. Source Types

Source
Peer-Reviewed Journals
Conference Proceedings
Acquisition Research Program Reports
Case Studies
GAO Reports
DoD Reports
Search Engine: Google & Google Scholar
DAU Acquisition Community Connection: *Commercial Off-the-Shelf Products and Commercial Services*
DAU Defense Acquisition Portal
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
Conferences/Practitioner Organizations: • Acquisition Research Symposium • IEEE International Conference on COTS-Based Software Systems • Software Engineering Institute/CMU • COTScon West 2000, Military Aerospace & Electronics

The massive amount of sources found was narrowed by inclusion and exclusion criteria (Table 3). 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 and Ormrod, 2005).

Table 3. 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 (Appendix A) was used to construct concept matrices (Webster and Watson, 2002) of barriers (Table 4) and success factors (Table 5). 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 and 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 casual inferences or predictions. Explaining theories does 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 the 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.

Reliability

Reliability refers to consistency. This means that the data analysis procedures must be repeatable. Details of the processes used are reported herein to facilitate a separate researcher duplicating the analysis. Additionally, ubiquitous, cited literature review methods were employed with which other researchers are undoubtedly familiar.

Validity

External validity – the extent to which findings of a sample apply to a population – is also known as generalizability. To ensure the findings herein are representative of the population of DOD COTS product usages, findings from DOD case studies were prioritized. Representation from different types of weapon systems platforms, different technologies, different industries, hardware and software COTS components, and cases from all three military departments and DOD civilian agencies were included. Additionally, only cases published since 2000 were considered to ensure recent COTS product usages since major commercial item legislation from the mid-1990s took root.

Internal validity concerns relationships. Relationships posited evolved from patterns in themes across sources. These themes were captured in a concept matrix linking themes to sources. Repeated concepts associated with COTS product use barriers and with success factors across sources suggested the existence of patterns (i.e., relationships). Additionally, the emerged patterns were then reconciled with the relevant underlying theories for consistency. The resultant relationships posited are shown in the COTS Product Usage Framework in Figure 2.

Results

Literature reviews begin with a definition of the topic (Hart, 1998). The following definitions, taken from the literature, ground the meaning of terms as referred to in this literature review. This discussion ensures a common meaning as that intended, which is particularly important in cases of multiple or diverse definitions.

Definitions

Commercial Off-The-Shelf (COTS)

COTS has been defined as: “products sold, leased or licensed to the public, [for which a] supplier is a commercial entity in the business of making a profit, integrators use the product without modification, [the] supplier retains intellectual property rights, [the] supplier provides product support and evolution, [and the] commercial market drives product evolution” (Grant, 2000, p. 5). According to the Federal Acquisition Regulation (FAR), a commercial item is defined as “that is of a type customarily used by the general public or by non-governmental entities for purposes other than governmental purposes” (FAR Subpart 2.101). Similar concepts include: government off-the-shelf (GOTS), modified off-the-shelf (MOTS), and non-developmental items (NDI).

COTS Software

The Navy has defined COTS software “as applications and tools that are ready-made by commercial vendors and are available for sale, lease, or license to the general public, as well as to the Federal Government” (DON, 2009, p. 2).

Engineering

Engineering is commonly defined as “the practice of organizing the design and construction of any artifice which transforms the physical world around us to meet some recognized need” (Hall and Rapanotti, 2016, p.5). Taking this definition into account, along with a critical review of many others in order to understand software engineering, Riehle (2008, p. 44) expounded upon the definition as:

"Engineering is the organization, application, and management of settled (dependable) knowledge using the tools of science, mathematics, and logic, along with knowledge, experience, and artifacts derived from previous engineering efforts, for reconciling conflicting forces/constraints, controlled within defined tolerances, to effect an economical, risk-averse, maintainable, fault-tolerant design toward the goal of a predictable outcome."

Systems Engineering

"Systems engineering refers to the practice of organising the design and construction of any system which transforms the physical world around us to meet some recognised need" (O'Halloran et al., 2017, p. 58).

Software Engineering

Software engineering is defined by the Institute of Electrical and Electronics Engineers as: "(1) The application of a systematic, disciplined, quantifiable approach to the development, operation and maintenance of software, that is, the application of engineering to software. (2) The study of approaches as in (1)" (IEEE, 1990).

Open Architecture (OA)

"Open Architecture means a type of architecture whose specifications are made public by its designers which allows users to make modifications to various components" (DOD AT&L, 2013, p. 138). "The acquisition of open architecture (OA) systems that can adapt and evolve through replacement of functionally similar software components is an innovation that can lead to lower cost systems with more powerful functional capabilities (Scacchi and Alspaugh, 2016, p. 163).

Open Source Software (OSS)

"There are many similarities in using OSS and COTS" (Hauge et al., 2010, p.1142). "Open Source Software is computer software for which the human readable source code is available for use, study, reuse, modification, enhancement, and redistribution by the users of that software" (DOD AT&L, 2013, p. 139). "The integration of OSS components is one of the most popular ways of adopting OSS, in particular in the software industry. From a sample of 146 OSS firms, 69.5% reported that they had adapted OSS to customer needs. In another sample of 769 companies 33% provide solutions which are based on OSS. Moreover, 48% of 62 software companies use OSS in their business, and in a sample of 569 software companies, 46.8% integrate OSS in their software systems" (Hauge et al., 2010, p. 1143).

"Interest in open source software (OSS) within the U.S. Department of Defense (DoD) and military services first appeared more than 10 years ago. More recently, it has become clear that the U.S. Defense community has committed to a strategy of acquiring software-intensive systems across the board that require or utilize an "open architecture" (OA) which may incorporate OSS technology or OSS development processes that can help Defense customer organizations to achieve better buying power . Why? Among the reasons identified is the desire to realize more choices among software component producers or integrators, as producers and integrators often act in ways that lock their customer organizations into overly costly and sometimes underperforming and difficult to sustain systems. One approach being explored focuses attention to agile and adaptive OA software components that are acquired and assembled (integrated) as C3CB system capabilities (assembled capabilities or AC) that are acquired and shared by multiple parties via independent "lines of efforts" acting within an ecosystem of producers, integrators, and consumer organizations. The goals of the AC approach include a shorter delivery and update cycle for mission components and an improved cybersecurity posture" (Scacchi and Alspaugh, 2016, p.164).

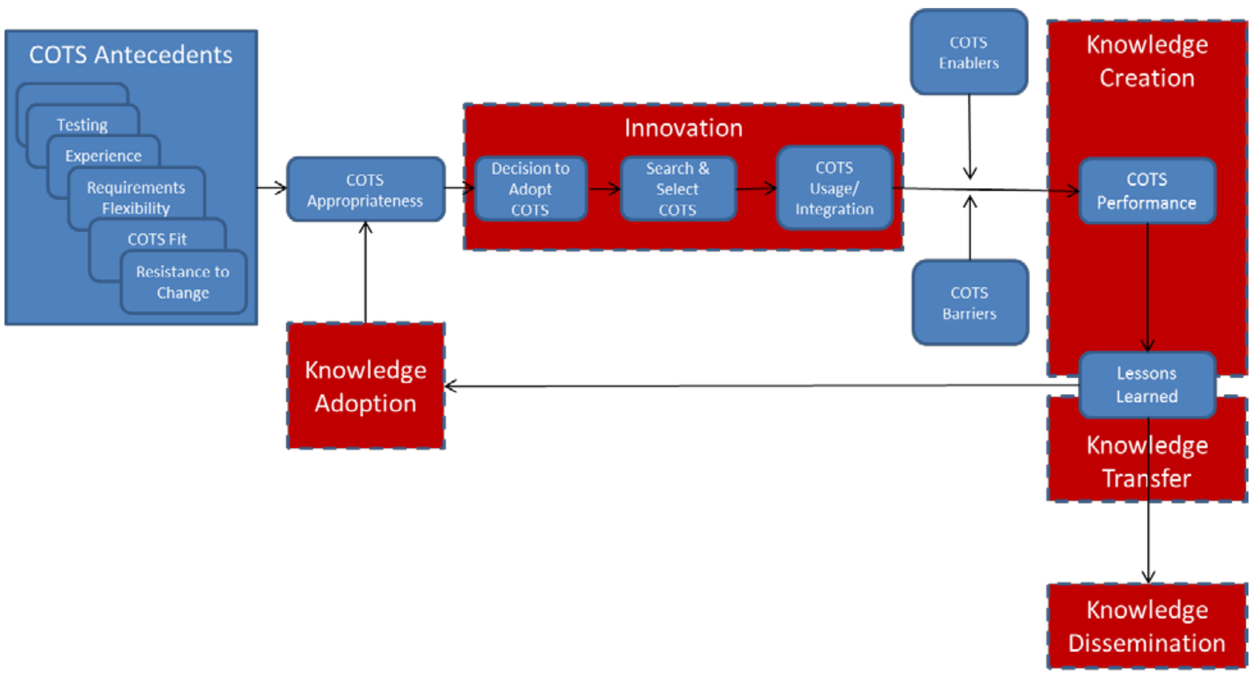
Literature Synthesis and Analysis

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 concept matrices in Tables 4 and 5 show the concepts and the color coding depicts how common concepts were combined (i.e., common colors). The central theme seemed to address the fitness of COTS products to the situation, henceforth termed *COTS appropriateness*.

Looking back to theoretical underpinnings, this construct resembles a popular model in the information systems literature – the technology acceptance model (TAM) (Davis, 1989). The two focal predictors of technology acceptance are *perceived usefulness* and *perceived ease of use*. Many of the 19 emerged antecedents could be considered aspects of these two predictors. The following discussion will explain COTS appropriateness and each of its antecedent factors. Then, these constructs are imposed on Beesley and Cooper's (2008) knowledge management framework explicated in the theoretical foundations section. See Figure 2 for a depiction of the comprehensive COTS product usage framework.

Figure 2. COTS Product Usage Framework



COTS Appropriateness

COTS appropriateness is the focal construct in the emerged COTS framework. Grant (2000, p. 31) concluded: "not enough emphasis has been placed on understanding and implementing the process to determine the applicability (that is, the appropriateness) of COTS." 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) mentioned the selection of inappropriate COTS components. Keil and Tiwana (2005) also mentioned the disastrous ramifications of selecting inappropriate COTS software. Couts and Gerdes (2010) questioned the appropriateness of COTS to meet the needs of some integrations. Cechich and Piattini (2007) offered 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 herein to measure COTS appropriateness (Appendix B). This scale is intended to assess the degree of appropriateness, measured on an interval scale of 1-7, 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.

- **<u>Fit between end user's needed (or desired) outcomes and the capabilities of the COTS product</u>.** One of DOD's lessons learned from early COTS implementations stated "If the gap is too great, commercial items may not be appropriate" (DOD, 2000, p. 8). Several studies mentioned the importance of a close fit. Modifying COTS products was mentioned in the context of a barrier to successful implementation by several sources (Grant, 2000; Hauge et al., 2010; Morrow, 2010; DOD, 2009; Baker, 2002). Furthermore, not modifying COTS products is mentioned as a success factor by several sources (GAO, 2005; Couts and Gerdes, 2010; GlobalPlatform, 2003). Prosnik (2003) and Grant (2000) explicitly mentioned the fit between requirements and COTS products as a success factor. This fit was the most frequently occurring antecedent found in the literature. The Air Force's decision to declare its aerial refueling tanker aircraft a commercial item - despite a lack of fit - allowed a bureaucrat to attain personal goals of favoring Boeing by sidestepping regulations requiring certified cost and pricing data (Branstetter, 2005; Larezos, 2008).
- **<u>Requirements flexibility</u>**. COTS products, as-is, often do not fully meet the end user's or technical authority's desired functionality. The old paradigm of the DOD specifying its needs then leaving it up to the supplier to make and deliver has come into question. Sometimes, an eighty-percent solution can suffice, particularly if it helps meet other program objectives such as delivery time to the user and budget constraints. Many sources mentioned the importance of bending the requirements to meet the capabilities of COTS products rather than bending the COTS products to meet the requirements, and how this results in success (Couts and Gerdes, 2010; Gansler and Lucyshyn, 2008; Grant, 2000; Jilani, 2008; Prosnik, 2003). Yang et al., in their proposed process for COTS-based applications, warned not to start with requirements. "Committing to requirements before performing design and glueware integration analysis will likely create architectural mismatch problems, often causing factor-of-four schedule overruns and factor-of-five budget overruns" (2005, p. 56). The Defense Science Board (DOD, 2009) offered another insight - that in many cases, "good enough" is also militarily useful. Hence, system usefulness may increase with faster delivery, lower risk, and lower cost. In the Palantir case (Brill, 2017), the Army refused to consider Palantir's common ability to tailor its software to suit client needs. Corroborating these findings, some sources mentioned inflexibility of requirements as a barrier (Rosa et al., 2013). Baker (2002), in his study of the Air Force T-3 Firefly tragedies, discussed the detrimental effect of over-specifying requirements.
- **<u>Post-adoption COTS product change preparedness</u>**. This antecedent to COTS appropriateness is dominant in the software realm. According to Kristin Baldwin (2007), the Deputy Director, Software Engineering and System Assurance, Office of the Under Secretary of Defense-Acquisition Technology & Logistics, "software life cycle planning and management by acquirers and suppliers is ineffective" (p. 8). This antecedent includes

related issues such as the ability to maintain configuration control, keeping track of components and their interrelationships, a lack of control over the COTS product's functionality, a lack of control over the COTS product's technological evolution, the number and frequency of supplier-pushed updates – which requires reintegration with parent hardware and software, and preparedness to manage such changes and issues. Sources cited managing configuration control as barrier (Grant, 2002) and, if done well, as a critical enabler (Gansler and Lucyshyn, 2008). Many sources cited the amount and frequency of supplier updates (Gansler and Lucyshyn, 2008; Grant, 2000). In the context of component-based software development, Jilani (2008) mentioned the challenge of keeping track of components and their interrelationships. Yang et al. (2005) and Reifer et al. (2003) discussed the importance of planning for and managing COTS product changes. Reifer et al. (2003) elaborated with advice to define a priori the refresh process for component-based software, and synchronize the COTS package updates with each other and with the organization's release and business cycle. They also recommended analyzing the impact of software version updates up front. Yang et al. (2005) offered six strategies for preparing for COTS changes, and attributed changes to the COTS product suppliers' perpetual ambitions for competitive differentiation. Thus, a situation characterized by COTS product change will undoubtedly endure.

- **A priori and post hoc testing**. The literature reveals two opposing sides to testing. Full traditional operational testing was identified as a barrier to COTS implementation (Boudreau, 2006). It follows that if a product is developed and sold for a particular commercial use, it is already tested (Gansler and Lucyshyn, 2008), and that further testing deteriorates the cost efficiency of using COTS products. Nonetheless, the submarine Acoustic RCIP program studied by Boudreau (2006) certainly involved extensive testing, just of a modified sort (e.g., at-sea testing). Many others find testing to be a success enabler. Horowitz and Lambert (2006) mentioned the necessity of testing of commercial products due to the inability to conduct design analysis and the constrained ability to predict integration problems, failures, non-performances, and security lapses. Baker (2002) cited unrealistic testing situations such as expert test pilots versus Air Force instructor pilots and students and the altitude of flying in Colorado versus being tested in Texas as contributing factors to the T-3 engine stalls that resulted in six deaths. In the Defense Acquisition University's software acquisition management course, Prosnik (2003) mentioned the need to conduct repeated testing with each new COTS product release. Thomas and Jajodia (2004) offer recommendations based on their experience with government ERP projects. They recommend extensive testing since correcting errors in a production system can increase costs ten-fold than fixing them during testing. Mariani and Pezze (2003) offered their *behavior, capture, test* method to test COTS components without requiring access to the source code. Testing appears to be important, yet, according to Baldwin

(2007), "software verification techniques are costly and ineffective for dealing with the scale of complexity of modern systems" (p. 8).

- **<u>Organizational resistance to change</u> (-)**. With respect to COTS product implementation, organizations continue to be hamstrung by a resistance to change. Gansler and Lucyshyn (2008) cited organizational culture as a barrier to successful COTS implementation. Charette (2013) partially attributed the failure of the Air Force's ERP program to the organization's resistance to changing business processes. Grant (2000) unveiled an aspect of fear of change associated with a fear of job loss and changing roles and responsibilities. The GAO (2015), in its examination of the Defense Logistics Agency's (DLA) Business Systems Modernization (BSM) program, mentioned parochialism as a barrier. Baron (2004), in her study of Air Force satellite ground station programs, found an association between a failure to modernize and historical precedent (also referred to as *organizational inertia*). Baron (2004) and Grant (2000) cite a paradigm of *design and build* versus *buy and integrate*. Brill (2017) explained in detail the Army's refusal to seriously consider Palantir's proven battlefield intelligence synthesizing, commercial-based software citing allegiance to a bureaucratic acquisition system, an insular defense ecosystem of defense contractors, the Pentagon, and Congress (even with its own surname, the *iron triangle*), and an organizational separation between the commanders on the ground and the buyers in the Pentagon. Even in the face of prior failure using a legacy acquisition process to acquire the Distributed Common Ground System-Army (DCGS-A) system to meet the same need, the Army would not consider Palantir as a viable option. Instead, the Army ventured on the same path to build upon a lacking DCGS-A system. On the inverse side and corroborating these effects, several sources also cited change management as a key success factor (Boudreau, 2006; Gansler and Lucyshyn, 2008; Prosnik, 2003).
- **<u>Open systems architecture (OSA)</u>**. Open system architecture was mentioned as a success factor in five sources (Grant, 2000; Prosnik, 2003). In their study of the Navy's E-2 Hawkeye aircraft, Gansler and Lucyshyn (2008) concluded: "the Open Architecture framework of the software now allows for uninhibited expansion and future growth of both the software and hardware components" (p. 20). Ford and Dillard (2009) demonstrated via simulation modeling the positive effects on performance of the incorporation of OSA in the Navy's Acoustic Rapid COTS Insertion program (RCIP). It makes sense that OSA would make COTS appropriate since OSA: (1) uses modular design and design disclosure, (2) uses reusable software, (3) facilitates interoperable joint platforms, (4) reduces lifecycle costs, and (5) promotes competition via alternative sources. Defense Science Board (DOD, 2009) noted the use of OSA on the Navy's P-8 Poseidon aircraft and the positive effects on costs.

- **<u>Robust COTS component evaluation and selection process</u>.** Transitioning to assemblers versus designers and builders means the buyer or systems integrator must, after acquiring the requisite market knowledge of the available COTS products, engage in an evaluation process to find the COTS products with the best technical fit at the optimal cost. Embedded in the scope of this antecedent is an accompanying evaluation of the source of the COTS. Thus, the evaluation of prospective suppliers a priori is important, and so is the continuing evaluation of COTS suppliers' performance after COTS selection and use. Ulkuniemi & Seppanen (2004), in their analysis of the emerging market of software components, concluded that some of the primary challenges were: scanning, evaluating, and selecting COTS components; analyzing component cost and value; and managing the overall component acquisition process. Clark et al. (2004) suggested that the methods of searching for software components need adjustments because of: (1) too narrow or too many prospective components, (2) errors in the component descriptions, (3) incompatibility, and (4) the system design. They offered a new method that performed better than that of ComponentSource on 11 criteria. In their extensive literature review of open source software (OSS) usage, Hauge et al. (2010) found that a major cost with OSS is learning and understanding new components. Knowledge and ability to meet requirements were the most important factors in choosing components. Julian et al. (2011) proposes the value hierarchy model as a useful set of COTS component selection criteria. Their model assesses criteria for the manufacturer, the product, and the technology in seven categories: (1) manufacturer capability, (2) manufacturer experience, (3) quality, (4) technical specifications, (5) logistics and support, (6) total costs of ownership, and (7) technology evaluation. Rendon (2007), in his analysis of modular open systems architecture (MOSA), noted that the use of supplier performance evaluation will be essential to MOSA development. Thomas and Jajodia (2004), in their advice on selecting ERP COTS software, cited as a success factor the evaluation of references to see how well the vendor has performed over time. Prosnik (2003) cited as a key to success the program manager evaluating products and suppliers.
- **<u>Marketplace knowledge</u>**. Grant (2000), Prosnik (2003), Yang et al. (2005), and Couts and Gerdes (2010) found that buyers need to understand the COTS product market. This make sense because the integrator's task, versus that of the developer, is to be aware of and to select the optimal COTS products or components from the optimal supplier. Buyers ignorant of what they are buying was identified as a barrier by Grant (2000). In the case of Palantir (Brill, 2017), a senior defense official attributed the Army's resistance to adoption of the commercial intelligence synthesis software to insufficient commercial market research. Prosnik (2003) recommended that buyers participate in user and industry groups in order to acquire the necessary knowledge about available COTS products. Additionally, buyers need to understand the technology roadmap of the COTS product suppliers (Grant, 2000). Ulkuniemi & Seppanen (2004) found that buyers should

understand the four types of COTS product markets because each one should follow a different acquisition process.

- **Leadership**. Leadership, or lack thereof, is a common target of critiques of management practices. In the case of COTS product implementation, the literature shows that attention is deserved. In some cases, there was no impetus to change; there was no burning platform (GAO, 2013). In other programs such as the Navy's Acoustic RCIP that restored the ability to detect enemy submarines, however, it was the burning platform (i.e., the threat to national security) that garnered the needed leadership attention (Grant, 2000). The GAO (2013) cited a lack of autonomy to implement change at the program level as reasoning behind the Air Force ignoring less costly, superior commercial solutions to satellite ground control stations. The Air Force's ERP project lacked an adequate governance structure which contributed to its cancellation (Charette, 2013). The program also experienced rapid leadership turnover – six program managers, five program executive officers, and 10 organizational designs. Conversely, strong leadership was attributed to the success of programs such as the DLA's BSM program (Gansler and Lucyshyn, 2008) and the Navy's Acoustic RCIP submarine program (Boudreau, 2006). The effect of leadership is not surprising given its role in reducing structural barriers and securing needed resources to accomplish unconventional feats such as those required by unfamiliar COTS product implementations.
- **COTS Experience**. Experience with using COTS products by all of the involved parties (i.e., the supplier, systems integrator, program team, and end user) is important. This is troublesome given that "the quantity and quality of software engineering expertise is insufficient for dealing with the scale of complexity of modern systems (Baldwin, 2007, p. 8). Grant (2000), in a study by the Air Force Scientific Advisory Board involving 34 COTS implementations, concluded that the contractor's experience with COTS product implementations contributed to program success. Prosnik (2003) suggested that COTS product buyers consult the expertise of the COTS product suppliers and from consultants. In the context of software integration, Horowitz and Lambert (2006) espouse the important effect of the experience of information technology staff in combining software components on success. They go further stating that: "it is critical to have team members who are aware of what the organization has done in the past, and where the relevant knowledge resides" (p. 290). Thomas and Jajodia (2004), in their study of EPR implementations, reinforce the importance of retaining the COTS acquisition team during program implementation and sustainment due to their acquired experience. The Defense Science Board (DOD, 2009) found that a lack of COTS experience was a barrier to implementation, and recommended program managers have commercial leadership experience and should ensure that program teams have leadership experience and domain expertise. The Air Force's ERP project (called ECSS) reinforces the importance of experience citing program manager turnover for the COTS implementation failure (Charette, 2013).

- **Complexity** (-). Grant (2000) and Gansler and Lucyshyn (2008) cited complexity as a barrier to COTS product usage. Cameron et al. (2015), in examining service oriented architecture, noted that complexity reduces software usefulness over time. “The fundamental requirement for future SOA systems within any heterogeneous environment is that the software be easily reconfigured so that it can be adapted to changing needs (p. 232).” They concluded that current approaches need to be revisited in order to reduce complexity. Examining the P-8 Navy aircraft, Naegle and Petross (2010) found that supply chain complexity is a limiting factor. O’Halloran et al. (2017) also noted a COTS-related complexity of the supply chain as barrier in safety systems engineering. In the context of component-based software development, Jilani (2008) found that problems arise when a component has to be modeled by integrating parts of functionality from different components or even from other suppliers.
- **COTS product lifecycles** (-). Suppliers upgrade their COTS products very frequently, approximately every 10 months (Yang et al., 2005). Releases lose technical support after an average of three releases (Yang et al., 2005). Thus, included in the scope of this factor is the process to manage obsolescence. Julian et al. (2011), in their proposed value hierarchy model for COTS component selection, includes technology refresh and insertion costs as one criterion to be evaluated. Grant (2000) found that diminishing manufacturing supply and obsolete parts were barriers to COTS implementation. He also attributed short product life cycles as a barrier. Grant (2000) also identified as a success factor the ability to manage obsolete parts.
- **Intellectual property constraints** (-). The GAO (2015) identified the ignorance of existing enterprise licenses for COTS products as a barrier to COTS implementations. Hauge and Ayala (2010, p. 1142) stated “it is challenging to decide what to contribute because of licenses and patents, and as user interface code can be considered a competitive advantage.” Scacchi and Alspaugh (2016) found that diverse, heterogeneous software intellectual property licenses were barriers. Conversely, Reifer et al. (2003) found that using flexible COTS-based systems (CBS) software licensing practices was a success factor. Prosnik (2003), in DAU’s COTS training content, attributed success to seeking enterprise licenses and negotiating licenses for volume discounts and transferable rights to the government.
- **COTS product training**. A lack of COTS product training was cited as a barrier to COTS product implementation (Baker, 2002; GAO, 2005). Baker’s (2002) case study of the T-3 Firefly flying screening aircraft for the Air Force implied a lack of training among the users of the aircraft (i.e., not sufficiently trained instructor pilots and students) as a barrier to COTS product success (and not as a barrier to COTS product adoption). Similarly, the GAO (2005), in a critique of an ERP implementation project, also cited a lack of training as a barrier in the successful implementation of COTS products. Likewise, GlobalPlatform (2003) recommended providing user training on the use of

new common access cards. The Air Force Scientific Advisory Board study (Grant, 2000) strongly advocated for COTS competency at all levels of the workforce, and recommended that, routinely, case studies and lessons learned be adopted in DAU's training. The study recommended education to understand COTS product usage, and not just how-to based training. Prosnik (2003) also recommended COTS product usage training.

- **Evaluating lifecycle TCO**. Grant (2000) found the lack of evaluating total cost of ownership (TCO) to be a barrier to COTS product usage. But most of the evidence of the impact of TCO is derived from the success factors. Grant (2000) and Prosnik (2003) identified the evaluation of TCO as a success factor in COTS product implementation. The Air Force Scientific Advisory Board study of COTS product usage (Grant, 2000) mentioned an imperative to evaluate TCO during source selection in order to determine the suitability of COTS products versus custom designs. It expounded by recommending that TCO models be developed to assist program teams. One of the lessons learned offered by Reifer et al. (2003) from their study of 16 COTS systems integrations was that the cost to maintain COTS-based systems is the same as or greater than that of developing custom software. To develop and maintain a line of *glue code* typically costs three times that of custom code (Reifer et al., 2003). Factors affecting TCO of COTS components include the: "Number of COTS packages that must be synchronized within a release, technology refresh and renewal cycle times, maintenance workload (the amount of effort software engineers expend to handle the task at hand) for glue code and wrapper updates, maintenance workload to reconfigure packages, market watch and product evaluation workload during maintenance, maintenance workload to update databases, maintenance workload to migrate to new standards, [and] COTS maintenance license costs" (Reifer et al., 2003, p. 95). "Inadequate attention is given to total life cycle issues for COTS/NDI impacts on life cycle cost and risk." (Baldwin, 2007, p. 8)
- **"Black box" design** (-). Proprietary, black-box designs and inaccessible source code pose an uncomfortable situation for engineers (Grant, 2000). Prosnik (2003) and O'Halloran et al. (2017) confirmed that invisible internals pose challenges. Horowitz and Lambert (2006) contend that "since there is no control of, or visibility into, existing vendor-provided software packages, the analysis-oriented systems engineering efforts on a development project are replaced with comparing vendor-stated specifications and carrying out test evaluations of the potential system components. Some very significant consequences of the lack of ability to perform design analysis include the limited ability to predict before testing: 1) system integration problems; 2) system capacity; 3) system performance; 4) system failure modes and responses; [and] 5) system security shortfalls" (p. 288). Couts and Gerdes (2010) highlighted the threat of a COTS component supplier going out of business and, for success, recommended gaining knowledge of the product's underlying coding language and technology.

- **Stakeholder buy-in**. On the Air Force's ERP project, Charette (2013) cited a lack of buy-in among the numerous logistics organizations as a contributing factor to the cancelled program. Prosnik (2003) cited a need to involve users and stakeholders early as key to success. Prosnik's training content was confirmed by the DOD common access card program (GlobalPlatform, 2003). Boudreau (2006) found that delivery lead time was favorably and strongly affected by stakeholder buy-in. The Submarine Tactical Requirements Group set requirements, and users provided feedback. End users were also heavily involved in the at-sea testing as well.
- **Contractual financial incentives**. Positive and negative incentives have successfully been used to motivate contractors to increase COTS product usage. Baron (2004), in a study of Air Force satellite ground control stations, found that a misaligned reward system impedes COTS product adoption. Informants reported that there was no incentive to adopt COTS products, and, conversely, there were incentives not to do so. Grant (2000) found that instilling financial incentives (negative) to the supplier to control sustainment costs is effective in attaining success. Prosnik's (2003) DAU training on COTS products concluded that long-term-focused incentives are a key to success. Rendon (2007), in an assessment of DOD's modular open systems architecture data, found that incentive fees, award fees, and award-term contract incentives are integral to success.
- **Communication**. The Defense Science Board (DOD, 2009) found that poor contractor team communication was a barrier to COTS product implementation. Another study involving 34 COTS product cases found that a collocated integrated product team led to success (Grant, 2000). Boudreau (2006) cited the seminal role of extensive communication between users, material developers, and contractors in the case of the Acoustic Rapid COTS Insertion program for the Navy's submarine sonar systems. He also found that mitigating organizational boundaries was important.

Decision To Adopt COTS Products

The decision to adopt COTS products follows from the level of appropriateness of COTS product usage. If the usage of COTS products is deemed sufficiently appropriate – given an assessment of the many considerations that determine appropriateness (Appendix B), then the program manager may decide to adopt COTS products.

COTS Search and Selection

Consistent with the literature, once a decision is made to adopt COTS products, prospective COTS products or components must be identified, evaluated, selected, and the supplier of each must also be evaluated and selected. This search and selection process can be performed in-house or by a systems integrator, depending on the magnitude of the program and the acquisition strategy.

COTS Usage

Once selected, the COTS products will then be used either as components to a larger system or as stand-alone solutions to satisfy a user's need.

Barriers To Effective COTS Usage

The extent to which the COTS products add value (i.e., perform or enable system performance to the level expected and required) will depend on the extent of presence of the barriers listed in Table 4. In other words, each barrier is posited to moderate the relationship between COTS usage and COTS product performance. Barriers will decrease the strength of said relationship. Of note, the barriers are the same as the antecedent factors denoted with a negative relationship above (-).

COTS Enablers

The extent to which the COTS products add value (i.e., perform or enable system performance to the level expected and required) will depend on the extent of presence of the enablers (i.e., success factors) listed in Table 5. In other words, each success factor is posited to moderate the relationship between COTS usage and COTS product performance. Enablers will increase the strength of said relationship. The enablers are the same as the antecedent factors denoted without a negative relationship indicator above (-).

COTS Performance

COTS performance is an outcome construct that can be measured by any of the following: performance levels, development time, acquisition cost, lifecycle or sustainment costs, product or system availability, product or system reliability, and supply base competition. Boudreau's (2006) case study of the Navy's acoustic rapid COTS insertion program found that COTS product usage decreases development time, lowers cost, and improves logistics performance. Once performance is validly assessed, knowledge is created (See COTS Framework in Figure 2.).

Lessons Learned

Once performance levels are assessed and compared to those expected, conclusions as to success, failure, and satisfaction are made. Reflections of events and decisions, in concert with the framework, can help identify how those results transpired. Once lessons are concluded, knowledge is again created. Then, generative learning occurs. Knowledge transfer occurs "when information has been reasoned over and incorporated in to the receiver's existing knowledge structures (Beesley and Cooper, 2008, p. 55). These conclusions of what and why will exist tacitly, but could also be codified into a tangible form (e.g., policies, directives, guidebooks, regulations, training, and education). Knowledge of lessons learned can be fed back to product managers, system owners, research and development centers, program executive officers, technical authorities, and users to create new weapon systems and capabilities. In this sense, knowledge is considered adopted which will, in turn, facilitate new innovation.

Knowledge Dissemination

Knowledge is considered disseminated by several means. Commonly, newly discovered knowledge, best practices, and lessons learned are incorporated into policies, laws, regulations, guidebooks, handbooks, online communities, and training and education content. The knowledge, then, is disseminated once individuals access the policies, laws, regulations, guidebooks, and complete training and education courses.

Interestingly, many of these 19 emerged antecedents resemble the COTS issues identified at the COTScon conference in 2000. That conference identified as issues, in order of priority: (1) integrating multiple COTS products, (2) cost versus benefit of upgrading, (3) requirements versus COTS capabilities, (4) testing in an operational context, (5) vendor relationships, (6) whether standards are good or bad, (7) cross platform portability, (8) API breakage, (9) acquisition and support strategies, (10) vendor responsiveness, (11) dormant functionality, (12) the definition of COTS, and (13) marketplace maturity (Kohl, 2000).

Table 4. Barriers to COTS Implementations Concept Matrix

Barrier	Grant (2000)	Gansler & Lucyshyn (2008)	GAO/AIMD (2000)	GAO (2013)	GAO (2005)	GAO (2004)	Prosnik (2003)	Scacchi & Alspaugh (2016)	Thompson et al. (2007)	Jilani (2008)	O'Halloran et al. (2017)	Cameron et al. (2015)	Curry et al. (2006)	Horowitz & Lambert (2006)	Naegle & Petross (2010)	Boudreau (2006)	Ford & Dillard (2009)	Charette (2013)	GAO (2006)	DODIG (2006a)	Julian et al. (2011)	Guntersdorfer & Kay (2002)	Mariani & Pezze (2007)	Ulkuniemi & Seppänen (2004)	Clark et al. (2004)	Rosa et al. (2013)	Hauge & Ayala (2010)	GlobalPlatform (2003)	Morrow (2010)	DOD (2009)	Baron (2004)	San Miguel et al. (2008)	Baker (2002)	Brill (2017)	SUM	SUM barriers & Success
Intellectual Property Rights (e.g., Licenses and patents)							X																				X								2	5
(Cyber)Security	X					X		X																											3	3
"Design and Build" vs. "Buy and Integrate" Paradigm	X																																		1	
People Issues (unrealistic leader expectations, altered roles and responsibilities, lack of skills, loss of control and job security)	X												X																				X		3	
Lack of policy prescribing COTS implementation decision process	X	X																																	2	3
Program Age (Timing)	X																																		1	
Technical Complexity	X	X										X																							3	6
Supply chain complexity											X				X																				2	
Risk	X																																		1	
Lower Contractor Profit	X																																		1	
Lack of evaluating total cost of ownership (TCO)	X																																		1	5
Prescribed COTS percentages from leadership	X																		X	X															3	
Modifying COTS for integration	X																										X		X	X			X		5	14
Resistance to change necessitated by COTS	X	X																X																X	4	11
Inflexible system requirements	X	X																								X								X	4	14
Differing software certification (e.g., SEI) standards for developers of COTS vs. non-COTS development	X																					X													2	
Buyer ignorance of what they are buying	X																																		1	10
Lack of market research																																		X	1	
Over-specification of requirements	X																																X		2	
Poor fit between requirement and COTS	X						X																												2	
Difficulty of maintaining configuration control	X																																		1	13
Lock-in to supplier's upgrade/refresh	X																																		1	
More rapid upgrade and refresh cycles increase costs	X	X					X	X																											4	
Diminishing manufacturing supply and obsolete parts	X																				X														2	5
Short COTS product life cycles	X																				X														2	
Proprietary Goods - Lock-in to a specific supplier – suppler leverage/power over the buyer	X	X							X																										3	3
Limited visibility into COTS product internals and behavior. Engineers can't access source code - "black box" - hidden proprietary design	X						X				X			X																					4	5
Organizational culture		X																X																	2	
Funding appropriations (i.e., colors of money) – COTS require procurement funds, RDT&E funds, and O&M funds for sustainment		X														X																			2	
Lack of training					X																												X		2	5

Table 4. Barriers to COTS Implementations Concept Matrix (cont.)

SUM barriers & Success	SUM	Brill (2017)	Baker (2002)	San Miguel et al. (2008)	Baron (2004)	DOD (2009)	Morrow (2010)	GlobalPlatform (2003)	Hauge & Ayala (2010)	Rosa et al. (2013)	Clark et al. (2004)	Ulkuniemi & Seppänen (2004)	Mariani & Pezze (2007)	Guntersdorfer & Kay (2002)	Julian et al. (2011)	DODIG (2006a)	GAO (2006)	Charette (2013)	Ford & Dillard (2009)	Boudreau (2006)	Naegle & Petross (2010)	Horowitz & Lambert (2006)	Curry et al. (2006)	Cameron et al. (2015)	O'Halloran et al. (2017)	Jilani (2008)	Thompson et al. (2007)	Scacchi & Alspaugh (2016)	Prosnik (2003)	GAO (2004)	GAO (2005)	GAO (2013)	GAO/AIMD (2000)	Gansler & Lucyshyn (2008)	Grant (2000)	
	0																																			Parochialism
8	2																															x			x	No impetus for change - no "burning platform"
	1																															x				Organization - lack of autonomy at program level to change
11	1																												x							Varying architectural paradigms across system components
	1																												x							Dependencies among system components
	2																	x										x								Unknown or unclear software architecture
	1																											x								Diverse, heterogeneous software IP licenses
3	3																				x				x			x								Integration of legacy (customized/"bespoke") and new components and systems
	1																											x								OSS evolution patterns transform software IP and cybersecurity requirements
	1																											x								Emergence of new business models for software distribution, cost accounting, and software distribution
	1																									x										In CBSD, problems that occur when two or more components have the same services with different representations.
	1																									x										In CBSD, problems that occur when a component has to be modeled by integrating parts of functionality from different components (or from other sources).
	1																									x										In CBSD, integrating two or more components and the resulting architecture does not cover the desired application requirements.
	1																									x										In CBSD, problems that occur when two or more integrated components with different implementations fail to interoperate.
	1																									x										In CBSD, keeping track of components and their interrelationships.
2	1																								x											Unstated expectations
	1																								x											Unjustified assumptions
	1																							x												Open standards for service invocation, asynchronicity and loose coupling
13	2		x																			x														Due to lack of ability to conduct design analysis, limited ability to predict before testing: 1) system integration problems; 2) system capacity; 3) system performance; 4) system failure modes
	1																				x															Classified information
	2		x																	x																Traditional end-to-end operational Testing
	1																			x																"The Joint Capability Integration and Development System (JCIDS) reviews occurred at a slower pace than the A-RCI/APB op tempo."
	1																	x																		Inadequate governance
	1																	x																		Firm-fixed price development contract
7	1																	x																		Personnel turnover (program managers)
	1																	x																		failure to understand its own legacy systems' data
	1																	x																		inability to define a transition plan
	1																	x																		lack of a sufficient execution plan
	1																	x																		unrealistic development environment

Table 4. Barriers to COTS Implementations Concept Matrix (cont.)

SUM barriers & Success	SUM	Brill (2017)	Baker (2002)	San Miguel et al. (2008)	Baron (2004)	DOD (2009)	Morrow (2010)	GlobalPlatform (2003)	Hauge & Ayala (2010)	Rosa et al. (2013)	Clark et al. (2004)	Ulkuniemi & Seppänen (2004)	Mariani & Pezze (2007)	Guntersdorfer & Kay (2002)	Julian et al. (2011)	DODIG (2006a)	GAO (2006)	Charette (2013)	Ford & Dillard (2009)	Boudreau (2006)	Naegle & Petross (2010)	Horowitz & Lambert (2006)	Curry et al. (2006)	Cameron et al. (2015)	O'Halloran et al. (2017)	Jilani (2008)	Thompson et al. (2007)	Scacchi & Alspaugh (2016)	Prosnik (2003)	GAO (2004)	GAO (2005)	GAO (2013)	GAO/AIMD (2000)	Gansler & Lucyshyn (2008)	Grant (2000)	
4	1																	X																		Mistrust & lack of buy-in
	2															X	X																			Establishing goals that only measure COTS use and not the benefits expected
	2															X	X																			Improperly classifying an acquisition as "commercial"
	1															X																				Misuse of simplified commercial contracting authority for other than intended purposes (e.g., save procurement lead time; avoid obtaining certified cost and pricing data)
	1														X																					Not rugged enough for military applications
	1														X																					Short warranties of COTS components (e.g., 1 year)
	2											X		X																						"It is difficult to identify and quantify the exact economic benefit of developing reusable software components."
	1												X																							Lack of control over functionality
	1												X																							Lack of control over COTS products' evolution
	1												X																							Lack of design for interoperability
11	1											X																								Scanning, evaluating, and selecting COTS components
	1											X																								Defining component warranties and liability
	1											X																								Managing the overall component acquisition process
	1										X																									Efficiently finding COTS products/components
	1									X																										Accurately estimating ERP costs and schedule
	1								X																											Cost with OSS learning and understanding new components.
	1								X																											Hard to assess providers' reputation
	1								X																											Estimating the time it takes for OSS integration
	1							X																												Integration: the military Services maintain their own networks, firewalls and communications infrastructure
	1					X																														DOD does not understand costs of more customized development (i.e., less COTS) because DOD costing models don't work well for COTS or COTS-based systems.
	1					X																														Programs are structured with insufficient flexibility to permit tradeoffs of production schedules with performance and life-cycle costs.
	1					X																														Organizational separation of the technical authority (who can make program decisions) from those responsible for cost and schedule precludes tradeoffs.
	1					X																														Lack of personnel expertise and experience
4	1					X																														Poor contractor team communication
4	1				X																															Misaligned reward system
	1				X																															Entrenched Networks
	1				X																															Historical precedent
	1			X																																Leasing

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 lifecycles, 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. Details may also be found in Appendix A. The source details were used to populate the barriers identified in Table 4. 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), timing of COTS decision. Decided to infuse COTS after the design.
- Air Force Depot Maintenance Management Information System (Grant, 2000), modified COTS by changing two million lines of code; project terminated. Modifications led to a loss of the software’s natural market-driven evolution, loss of supplier support, and complexity.
- Air Force Expeditionary Combat Support System (ECSS), the Service’s global supply chain management COTS-based (Oracle and Computer Science Corporation) ERP (Charette, 2013). The USAF Spent $1.03B over seven years with no delivered system. The ERP implementation was to replace 240 legacy systems. Four contributing causes of failure included: governance, tactics, techniques, and procedures, a firm-fixed price contract for development, difficulty of change, personnel and organizational churn, a failure to understand its own legacy systems’ data, failure to define the future architecture, inability to define a transition plan, lack of a sufficient execution plan, an unrealistic development environment, and mistrust among Air Force logistics organizations and lack of buy-in.
- Air Force KC-767A Tanker Lease (DODIG, 2006a; DODIG, 2004a; GAO, 2006). Aircraft did not meet the statutory definition of a commercial item; no commercial market existed (Larezos, 2008).

- Air Force C-130J (DODIG, 2006a; DODIG, 2004b). "No commercial version of the plane existed and sales of the C-130J were for Government programs."
- Air Force and Navy T-6A Texan II, Joint Primary Aircraft Training System (JPATS) (DODIG, 2006b). It was based on the Hawker Beechcraft Pilatus PC-9 aircraft. Started as a FAR Part 15 (non-commercial) acquisition, then lots 7 – 13 were converted to FAR Part 12 (commercial) acquisitions. The aircrafts' unit prices increased substantially between Lot 8 and Lot 9. Acquisitions beyond lot 13 were later converted back to FAR Part 15 procedures. Military-unique requirements at program inception constituted 5% of requirements. This ratio later grew to 70% of requirements (Witek, 2015).
- 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)

Table 5. COTS Implementation Success Factors Concept Matrix

	Grant (2000)	Gansler & Lucyshyn (2008)	GAO (2005)	Prosnik (2003)	Jilani (2008)	Cameron et al. (2015)	Curry et al. (2006)	Horowitz & Lambert (2006)	Boudreau (2006)	Ford & Dillard (2009)	Rendon (2007)	Julian et al. (2011)	Thomas & Jajodia (2004)	Mariani & Pezze (2007)	Ulkuniemi & Seppänen (2004)	Lobur (2011)	Yang et al. (2005)	Reifer et al. (2003)	Lobur (2011)	Couts & Gerdes (2010)	Morisio et al. (2002)	GlobalPlatform (2003)	Morrow (2010)	DOD (2009)	Tran (2012)	Brill (2017)	SUM	SUM barrers & Success
COTS Implementation Experience	x							x					x														3	
Hardware (vs. software)	x																										1	
Well-defined, well-documented processes	x																										1	
COTS not modified	x		x	x																x		x					5	
Flexible requirements (conform to COTS vs. modify COTS)	x	x		x	x												x			x				x			7	
Contractor's COTS experience	x																										1	
Open system architecture	x	x		x						x														x			5	
Trade study process	x																										1	
Understand the marketplace	x			x													x			x							4	
Similarity of COTS application and COTS features	x			x																							2	
Collocated IPT	x																										1	
Strong leadership	x	x							x																		3	
Use software “wrappers” that limit what software can do.	x																										1	
Customer mandate to use COTS	x																										1	
Buyer understands the supplier's technology road map	x																										1	
Instill financial (negative) incentives to the supplier to contain sustainment costs	x			x																							2	
Up-front awareness of impact of upgrades/refresh on TCO	x																										1	
TCO models	x																										1	
Systems to manage obsolete parts	x																										1	
Training and education on COTS systems	x			x																		x					3	
Develop a policy as a framework for COTS success	x																										1	
Capture lessons learned and best practices regularly	x			x							x																3	3
Develop personnel evaluation techniques	x																										1	
Change management is critical.		x		x					x																		3	
IT system (ERP) should be deployed in increments with much testing.		x																									1	
Configuration control is critical.		x																									1	
Involve end-users and other stakeholders early & attained buy-in				x					x													x					3	
Use domain experts and consultants from the COTS products' suppliers				x																							1	
Use prototypes and pilots to gain product insight				x				x					x														3	
Negotiate system context and product tradeoffs				x																							1	
Participate in user and industry groups				x																							1	
Live by the COTS Business Case				x																							1	
Negotiate Licenses & Supplier Relationships				x																							1	

Table 5. COTS Implementation Success Factors Concept Matrix (cont.)

Factor	Grant (2000)	Gansler & Lucyshyn (2008)	GAO (2005)	Prosnik (2003)	Jilani (2008)	Cameron et al. (2015)	Curry et al. (2006)	Horowitz & Lambert (2006)	Boudreau (2006)	Ford & Dillard (2009)	Rendon (2007)	Julian et al. (2011)	Thomas & Jajodia (2004)	Mariani & Pezze (2007)	Ulkuniemi & Seppänen (2004)	Lobur (2011)	Yang et al. (2005)	Reifer et al. (2003)	Lobur (2011)	Couts & Gerdes (2010)	Morisio et al. (2002)	GlobalPlatform (2003)	Morrow (2010)	DOD (2009)	Tran (2012)	Brill (2017)	SUM	SUM barrers & Success
Realistic budget for: market research, continuous eval, reacting to product releases, (re)integration				x																							1	
Flexible contract vehicles				x																							1	2
CBSD documentation of the information needed to understand all the required functions and the user's documentation completely described all user-callable functions in the component.					x																						1	
Black box testing that may be effective for COTS components include test case generation by equivalence classes, error guessing and random tests.					x																						1	
In CBSD, real-time detection, diagnosis, and handling of software faults.					x																						1	
A consistent granularity in service functionality						x																					1	
industry standard interface							x																				1	
Communication between users, material developers, and contractors									x																		1	
Organizational boundaries minimized									x																		1	
Data-driven testing (Build-Test-Build)									x																		1	
Peer review of new developments									x																		1	
Verify algorithms before implementation									x																		1	
Continuing assessments and measurement									x																		1	
Program manager who is: technicall competent, proactive, and disciplined/structured									x	x																	2	
Continuous requirements development, technology development, and advanced development.										x																	1	
Transparent assessment by objective, diverse team of experts prevented solution bias.										x																	1	
Industry's early involvement and participation in developing requirements and acquisition strategy											x																1	
Incentive fees, award fees, and award-term contract incentives											x																1	
Supplier performance evaluations/Contractor Performance Assessment Reports (CPAR)											x																1	
Designers develop specifications that allow for a wide range of implementations.												x															1	
Robust COTS component evaluation and selection process				x								x								x							3	
In selecting ERP COTS software, evaluate references to see how well the vendor has met requirements over time.				x									x														2	
In ERP projects, determine the scope - which processes will be automated and which systems will be replaced.													x														1	
Implement these ERP functions first: budget execution, general ledger accounting, accounts payable, and accounts receivable.													x														1	
Project team must understand: the existing business processes and those embodied in the ERP software.													x														1	
In ERP projects, don't reengineer the business processes before selecting the COTS software.													x														1	
In ERP projects, limit the amount and detail of historical data to be converted.													x														1	
For ERP projects, retain implementation team for post-implementation support.													x														1	

Table 5. COTS Implementation Success Factors Concept Matrix (cont.)

SUM barrers & Success		SUM		Brill (2017)	Tran (2012)	DOD (2009)	Morrow (2010)	GlobalPlatform (2003)	Morisio et al. (2002)	Couts & Gerdes (2010)	Lobur (2011)	Reifer et al. (2003)	Yang et al. (2005)	Lobur (2011)	Ulkuniemi & Seppänen (2004)	Mariani & Pezze (2007)	Thomas & Jajodia (2004)	Julian et al. (2011)	Rendon (2007)	Ford & Dillard (2009)	Boudreau (2006)	Horowitz & Lambert (2006)	Curry et al. (2006)	Cameron et al. (2015)	Jilani (2008)	Prosnik (2003)	GAO (2005)	Gansler & Lucyshyn (2008)	Grant (2000)	
		1														X														Dynamic analysis and testing of COTS component compatibility
		1													X															Buyers understand the COTS component market type
		1												X																In a COTS business process software implementation, the role of "user coordinators"
		1											X																	Lack of a project plan
		1											X																	Evaluate the COTS project based on risk exposure involved in selecting the wrong combination rather than on COTS products' costs.
		2										X	X																	Prepare and manage post-deployment COTS changes
		1										X																		Define a priori the refresh process for CBSs, and manage them so COTS updates can be synchronized
		1										X																		COTS software capability and quality evaluation must continue during the maintenance phase.
		1										X																		Understand the post-deployment cost drivers.
		1										X																		Spend significant time and effort up front to analyze the impact of software version updates
		1										X																		Use Flexible CBS software licensing practices
		1										X																		Use wrappers to protect a CBS from unintended
		1									X																			Employ the role of "user coordinator" who writes specifications for vendor customizations, develops
		1								X																				Use a systems integrator when appropriate
		1								X																				Know the product's underlying coding language and technology in the event that the vendor goes out of business
		1								X																				Periodically assess the product line's stability.
		1								X																				Use a test installation
		1							X																					Architectural issues, especially the difficulties of integrating components, must be considered
		1						X																						Close relationship with suppliers
		1						X																						a good roadmap identifying different communication types involved and maintaining control over firewalls
		1					X																							Receiving DoD's highest "DX" priority rating
		1					X																							Integrating low-level COTS and MOTS subsystems
		1					X																							Using multiple sources for production
		1					X																							creativity on the part of their subsystem integrators
		1				X																								"Other Transaction" authority
		1				X																								Spiral development
		1			X																									IT Strategy (helps customer meet deadline & reacts to environmental pressure)
		1			X																									Strategic decision-making process
		1		X																										Legislation for Commercial Item Preference

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, stakeholer 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. The source details were used to populate the enablers identified in Table 5.

- DOD Common Access Card (GlobalPlatform, 2003).
- Air Force Manufacturing Resources Planning (MRP) (Grant, 2000), COTS modification not allowed, successful deployment.
- Advanced Amphibious Assault Vehicle (AAAV) (Grant, 2000)
- New Attack Submarine and Acoustic Rapid COTS Insertion (ARC-I) (DOD, 2009; Grant, 2000; Boudreau, 2006; Ford and Dillard, 2009), cost savings in development, acquisition, and support costs; development time reduced; performance improved.
- Navy Sea Fighter (FSF-1) (DOD,2009)
- Airborne Warning and Control System (AWACS) upgrade; relaxed unnecessary requirements (Grant, 2000)
- Navy E-2 Hawkeye Early Warning Program (Gansler and Lucyshyn, 2008)
- Army Light Utility Helicopter (Gansler and Lucyshyn, 2008)
- DLA Business System Modernization (BSM) (Gansler and Lucyshyn, 2008)
- Army's General Fund Enterprise Business System (GFEBS), enterprise, web-enabled, financial asset and accounting management system. Based

on customized SAP COTS software. “GFEBS Increment I is meeting the Army’s financial business needs extremely well” (Kendall, 2015, p. 9).

- “Lightweight Autonomous Underwater Vehicles (AUVs) were developed for Naval Special Warfare (NSW) Group 4 search and survey missions from a commercial AUV baseline through integration of commercial off-the-shelf (COTS) hardware components, and through software development for enhanced on-board Command and Control functions” (Incze, 2011, p. 1955). Development resulted in on-time, successful factory acceptance testing and delivery of three contracted vehicles.
- Navy P-8 Poseidon maritime patrol and reconnaissance aircraft (DOD, 2009; Naegle and Petross, 2010).
- Air Force C-5 Reliability Enhancement and Re-Engining Program (RERP) (Lorell et al., 2017). The program replaces the C-5’s General Electric (GE) TF39 engine with GE’s more reliable COTS F138-GE-100 turbofan engine. The RERP program experienced technical, funding, and schedule issues leading to a Nunn-McCurdy breach in 2007. Issues were attributed to: (1) cracks and corrosion in the 1960s-era aging aircraft, (2) schedule slippage of the separate avionics modernization program, (3) additional costs for touch labor and supplier parts, and (4) unexpected redesign of the engine pylons and reinforcing the wing. The program was restructured by removing the problematic A-model aircraft reducing the total from 112 C-5s to 52 B models. The resulting total cost growth was only 22 percent and two percent for RDT&E. Following restructuring, the program experienced few technical issues attributed to the use of mature, commercial technology.
- Air Force and Navy Joint Direct Attack Munition (JDAM) (Grant, 2000; Lorell et al., 2017). The program stayed on schedule and experienced negative 12 percent unit cost growth. “Competing contractors were required to conduct trade studies, commercial parts testing, prototyping, and extensive technology demonstrations prior to MS B. There was a heavy focus on incorporating the maximum amount of COTS parts, components, and technology” (Lorell et al., 2017, p. 30). The USAF relaxed unnecessary requirements.
- Air Force Small Diameter Bomb (SDB I) (Lorell et al., 2017). The program experienced a 16 percent negative cost growth. The wide use of COTS parts contributed to the production of a low-cost, quality, reliable and maintainable system.
- Air Force Wideband Global SATCOM (WGS) System (Lorell et al., 2017). Block 1 of the program experience only a nine percent unit cost growth. This program was considered to be a COTS item; thus, it was procured under FAR Part 12 following streamlined commercial item acquisition procedures. WGS incorporated commercial parts and processes developed by Boeing for commercial communications satellites.

- Mine Resistant Ambush Protected vehicles (MRAP) (Morrow, 2010)
- Army M-ATV (Morrow, 2010)
- Aegis Ballistic Missile Defense System (Lockheed-Martin, 2017)
- Defense Healthcare Management Systems Modernization (DHMSM), DOD's $4.3 billion program to modernize its electronic healthcare records adopting Cerner's COTS application (DODIG, 2016b; Landi et al., 2017).
- Army's Single Stock Fund (SSF) program (Alcide, 2006). Merged several supply chain transformation initiatives into a global Single Army Logistics Enterprise (SALE) based on the commercial SAP ERP software.
- USMC utility task vehicle (UTV) program. (Tadjdeh, 2017)
- Army Ka-Band Satellite Transmit And Receive System, AN-GSC-70(V). (Stein, 2006)

Policies, Law, Regulations, and Directives

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

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. With greater attention recently on the budget resulting from the Budget Control Act of 2011, coupled with the realization that the pace of technology is accelerating and that adversaries are leveraging commercial technology, there has been recent renewed activity in the amount of law, policy, regulation, and directives. Table 6 displays the history and trends.

Table 6. COTS-Related Policies, Laws, Regulations, and Directives

Source	COTS Content
Policies	
OUSD AT&L 1996 Buying Commercial and Non-development Items, Handbook S-2	Guidance on the procurement of commercial items
J-STD-016-1995 / IEEE 12207 (replaced DoD-Std-2167A, replaced by MIL-STD 498)	Standard for Defense System Software Development that follows a waterfall development process. V-model development lifecycle.
Office of the Under Secretary of Defense (OSD) for Acquisition and	Distributed the "Commercial Item Acquisition: Considerations and Lessons

Source	COTS Content
Technology July 14, 2000 Memo	Learned" handbook dated 26 Jun 2000.
Office of the Under Secretary of Defense (OSD) for Acquisition and Technology January 5, 2001 Policy Memorandum	Set commercial contracting quotas. Established two commercial acquisition goals to be achieved by the end of fiscal year 2005: • "double the dollar value of commercial acquisition contract actions awarded in 1999" • "increase the number of commercial contract actions awarded to 50 percent of all contract actions."
Defense Acquisition Guidebook, Chapter 3, Systems Engineering	Covers COTS considerations in systems engineering
August 2004, Assistant Secretary of the Navy (Research, Development & Acquisition) (ASN (RDA)) policy statement	Developed a single Navy-wide open architecture to account for surface, air, submarine, C41, and space domain unique requirements.
2005 DoD Enterprise Architecture Technical Reference Model	DoD Service Oriented Architecture Policy
2007 DoD Global Information Grid Architecture Vision	DoD Service Oriented Architecture Policy
2007 DoD Net-Centric Services Strategy	DoD Service Oriented Architecture Policy
OUSD AT&L Commercial Item Handbook, version 2.0	This handbook is currently being updated.
Guidebook for Acquisition of Naval Software-Intensive Systems	Provides "background information, enterprise-wide policy, guidelines, proven alternatives, access to additional subject matter expertise, and amplifying detail for key software acquisition activities" (p. ES-1)
American Bureau of Shipping (ABS) Naval Vessel Rules	Allowed the large volume of lower-risk hull, mechanical, and electrical certification work to be done by ABS for execution during the Detail Design and Construction phase of a program.
OMB Memorandum M-15-14: Management and Oversight of Federal Information Technology	Instructions for implementing the FITARA.
OMB Circular A-11, Preparation, Submission, And Execution Of The Budget, July 2016, Supplement, Capital Programming Guide v. 3.0	"Large, complex implementations of COTS solutions should be broken down into manageable components of useful functionality to reduce risk."
OMB Circular A-130, Managing Federal Information as a Strategic	"Decisions to improve, enhance, or modernize existing IT investments or to

Source	COTS Content
Resource, July 28, 2016.	develop new IT investments are made only after conducting an alternatives analysis that includes both government-provided (internal, interagency, and intra-agency where applicable) and commercially available options, and the option representing the best value to the Government has been selected.”
Laws	
Competition in Contracting Act of 1984	“Required promotion of the use of commercial products whenever practicable.”
Federal Acquisition Streamlining Act of 1994 (Public Law 103-355, Section 8104)	Established a preference for commercial items, including non-developmental items (NDI). Streamlined contracting for commercial items. Defined commercial items. Defined NDI.
Section 4201 of the National Defense Authorization Act for Fiscal Year 1996 (Public Law 104-106, Section 357, February 10, 1996)	“Amended the commercial item exception to the requirement that contracting officers obtain certified cost or pricing data to substantiate price reasonableness determinations. This amendment broadened the exception to apply to all commercial items. Previously, it applied only to those commercial items for which there was an “established catalog or market price” through sales in substantial quantities to the general public.”
The Clinger-Cohen Act of 1996, Public Law 104-106	Improved the acquisition and management of IT. Eliminated certified cost or pricing data for commercial items and cost accounting standards. Allowed simplified acquisition procedures for commercial items.
Services Acquisition Reform Act of 2003	“Allowed different types of contracts to be treated as commercial acquisition under certain circumstances.”
National Defense Authorization Act of 2001,Section 811 of Public Law 106-398	To improve tracking and management of information technology products and services by DOD, the SECDEF shall provide for the collection of the data - whether the products or services are categorized as commercially available off-the-shelf items, other commercial items,

Source	COTS Content
	non-developmental items other than commercial items, other noncommercial items, or services.
Federal Information Technology (IT) Acquisition Reform Act (FITARA) of 2014	Directs the GSA to develop a strategic sourcing initiative to enhance government-wide acquisition. Requires CIOs and investment program managers of specified agencies to certify at least quarterly the accuracy and risks associated with such investments. Risk rating includes cost and schedule. Allows the Director to withhold development, modernization, or enhancement funds until high risk investment's root causes are identified and determines there is sufficient capability to deliver the remaining planned increments within the planned cost and schedule
National Defense Authorization Act of 2013, Section 831	DOD must: Issue guidance on standards for determining price reasonableness; Ensure that requests for uncertified cost information, for the purposes of evaluating price reasonableness, are sufficiently documented; Develop and begin implementation of a plan to train the acquisition workforce in the use of certain authorities for evaluating price reasonableness when procuring commercial items; and Develop a cadre of experts within DOD to provide advice to the acquisition workforce with regard to commercial item authorities.
National Defense Authorization Act of 2015	Made DOD's authority to use simplified acquisition procedures for certain commercial items permanent.

Source	COTS Content
National Defense Authorization Act of 2016	UOSD AT&L must issue guidance to acquisition officials of the Department of Defense to fully comply with the requirements of section 2377 of title 10, United States Code,: that the head of an agency may not enter into a contract in excess of the simplified acquisition threshold for information technology products or services that are not commercial items unless the head of the agency determines in writing that no commercial items are suitable to meet the agency's needs that market research is conducted to inform price reasonableness determinations.
National Defense Authorization Act of 2017	Established a preference for particular commercial services by prohibiting a contract above $10 million for certain services (e.g., facilities-related or knowledge-based) that are not commercial unless a written determination is made that a commercial service cannot meet the agency's needs. Requires DOD to use commercial or non-government standards instead of military standards and specifications unless no practical alternative exists to meet user needs.
Title 10, United States Code, Section 2377	Preference for acquisition of commercial items
Title 10, United States Code, Section 2501	National Security Objectives for National Technology and Industrial Base – purchase from U.S.-only sources
Title 10, United States Code, Section 2533a, "Berry Amendment"	Requires that food, clothing, fabrics, fibers, yarns, textiles, and hand or measuring tools be grown, reprocessed, reused, or produced in the United States
Section 879 of the National Defense Authorization Act (NDAA) for FY 2017 (Public Law 114-328)	Establishes Commercial Solutions Opening pilot program using Other Transaction Authority for commercial items and services
National Defense Authorization Act of 2017, Section 805, MOSA Public Law 114-328	Establishes requirements for MOSA in MDAs to enable incremental development, enhanced competition, innovation, and interoperability

Source	COTS Content
Regulations	
DoD Instruction 5000.02, Operation of the Defense Acquisition System	Requires the consideration of COTS items during concept refinement.
DoD 5010.12M, Procedures for the Acquisition and Management of Technical Data	Procedures for the Acquisition and Management of Technical Data
Federal Acquisition Regulation (FAR)	Procedures for acquiring commercial and non-developmental items
Defense Federal Acquisition Regulation Supplement (DFARS)	Procedures for acquiring commercial and non-developmental items
Navy Marine Corps Acquisition Regulation Supplement (NMCARS)	Procedures for acquiring commercial and non-developmental items
SECNAVINST 5000.2E, Department Of The Navy Implementation And Operation Of The Defense Acquisition System And The Joint Capabilities Integration And Development System	"The solution strategy shall: (f) Contain a recommended execution strategy that considers a combination of any or all of the following options: COTS and Government off-the-shelf;…" "Ensuring compliance with Common Criteria National Information Assurance Partnership (NIAP) framework,…" "Non-developmental items or commercial off-the-shelf (COTS) items shall be shown to be operationally effective and suitable for their intended use and capable of meeting their allocated RAM, including built-in-test requirements."
OPNAV Instruction 1500.76C, Naval Training Systems Requirements, Acquisition, And Management	A preliminary NTSP [Navy training systems plan] is required 6 years prior to system initial operational capability (IOC) for ACAT I and II programs requiring military construction (MILCON), and a final NTSP is required by the earliest date for programs meeting the following criteria: Three months prior to IOC for rapid acquisition programs such as non-developmental item, COTS, rapid deployment capability, abbreviated acquisition program, and urgent need programs.
SECNAV 5000.42, Accelerated Acquisition For The Rapid Development, Demonstration And Fielding Of Capability	Rapid Deployment Capability (RDC): A MACO [Maritime Accelerated Capability Office] program for which a Commercial-off-the-shelf, Government-off-the-shelf, or non-developmental solution, or an engineering

Source	COTS Content
	modification to an existing capability can provide a solution to an urgent need. The Chief of Naval Operations (CNO), the Commandant of the Marine Corps (CMC), and the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN (RD&A)) shall determine the most appropriate path to resolve priority Naval needs. Those paths could include the traditional GFM, PPBES, and DAS processes, or in cases where schedule considerations warrant, include MACO programs or RPED projects
SECNAV 5230.15, Information Management/Information Technology Policy For Fielding Of Commercial Off The Shelf Software	It is the policy of the Department of the Navy that all COTS software in use across the Department shall be vendor supported. OSS [open source software] shall be treated as COTS… Implementation shall also be reviewed in preparation for Joint Capabilities Integration and Development System (JCIDS) and acquisition milestone and gate reviews of IT/NSS systems, which are dependent on use of COTS software components.
SECNAV 5230.14, Information Technology Portfolio Management Implementation	MALs [mission area leads] shall execute the following: Advocate information sharing, collaboration, and best practices to include the use of commercial off-the-shelf (COTS) products. SECNAV, Navy and USMC FAMs [functional area managers] shall execute … the following IT PfM responsibilities: Review the performance of all FA [functional area] investments against capability requirements, costs, and schedules. Reviews must address compliance with net-centric criteria, DoD/DON netcentric data strategy goals, MA [mission area] architectures, transition plans, and other MA/FA criteria (such as the use of COTS products). Make recommendations to the MA and milestone decision authority (MDA), as appropriate.
DoD Instruction (DoDI) 5200.44, Protection of Mission Critical	Defines supply chain risk management. Defines software assurance as “the level of

Source	COTS Content
Functions to Achieve Trusted Systems and Networks (TSN)	confidence that software functions as intended and is free of vulnerabilities, either intentionally or unintentionally designed or inserted as part of the software throughout the lifecycle." Applicable systems must "(1) Reduce vulnerabilities in the system design through system security engineering. (2) Control the quality, configuration, and security of software, firmware, hardware, and systems throughout their lifecycles, including components or subcomponents from secondary sources."
Directives	
SECDEF Memorandum, 29 Jun 94, "Specifications & Standards – A New Way of Doing Business" (a.k.a., The "Perry Memo")	Directs Service Secretaries to increase use of performance and commercial specifications and standards (vs. MILSPECs).
DOD Directive 5000.01, The Defense Acquisition System	Program managers must examine and adopt commercial practices and electronic business systems that reduce cycle time and cost.
USECDEF/AT&L Memorandum, 14 Sep 10, "Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending"	Require open systems architectures and set rules for acquisition of technical data rights.
USECDEF/AT&L Memorandum, 3 Nov 10, Implementation Directive for Better Buying Power - Obtaining Greater Efficiency and Productivity in Defense Spending	Conduct a business case analysis and engineering tradeoff analysis, at Milestone B, that outlines the open systems architecture approach and technical data rights to be pursued to ensure a lifetime consideration of competition.
Directive-Type Memorandum 11-009, Policy for Defense Business Systems (DBS)	Redesign the processes that the system supports to reduce costs, improve effectiveness, and maximize the use of COTS technology. It is essential that the PM have requisite experience associated with relevant commercial-off-the-shelf (COTS) business applications and architectures.
USECDEF/AT&L Memorandum, 13 Nov 12, Better Buying Power 2.0: Continuing the Pursuit For Greater Efficiency and Productivity in	Enforce open system architectures and effectively manage technical data rights

Source	COTS Content
Defense Spending	
USECDEF/AT&L Memorandum, 24 Apr 13, Implementation Directive for Better Buying Power 2.0: Achieving Greater Efficiency and Productivity in Defense Spending	Components will describe how they have considered OSA during their milestone reviews. Relevant Justification and Approval waivers required for sole source contracts will include a discussion on how the program will take advantage of Open Business Model practices to break vendor-lock to minimize future sole source requests.
USECDEF/AT&L Better Buying Power 3.0 White Paper, 19 Sep 14	Do a better job of ensuring that designs are modular and that that competitors have the opportunity win their way onto programs.
USECDEF/AT&L Memorandum, 9 Apr 15, Implementation Directive for Better Buying Power 3.0: Achieving Dominant Capabilities Through Technical Excellence and Innovation	Remove barriers to commercial technology utilization. Train the workforce on how to access commercial technology and products. Emphasize technology insertion and refresh in program planning. Use Modular Open Systems Architecture to stimulate innovation. DAU will establish a Community of Practice for rapidly acquiring Commercial Off-the-Shelf products and Commercial Services.
DoD Open Systems Architecture Contract Guidebook for Program Managers, v.1.1, June 2013	Procedures for open systems architecture
Office of the Secretary of Defense DPAP memorandum, 2 Sep 16, "Commercial Items and Determination of Reasonableness of Price for Commercial Items"	Requirements for commercial item determinations and establishing price reasonableness

Previous Recommendations for DOD COTS Implementation

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 here (Table 7).

Table 7. Previous Recommendations for DOD COTS Implementations

Source	Recommendation
GAO-04-678	Require program managers, working with software assurance experts, acquisition personnel, and other organizations as necessary, to specifically define software security requirements, including those for identifying and managing software suppliers. These requirements should then be communicated as part of the prime development contract, to be used as part of the criteria to select software suppliers.
GAO-04-678	Based on defined software security requirements, require program managers to collect and maintain information on software suppliers, including software from foreign suppliers.
GAO-04-678	Require the Office of the Assistant Secretary of Defense for Networks and Information Integration and the Office of the Undersecretary of Defense for Acquisition Technology and Logistics, as part of their role to review, oversee, and formulate security and acquisition practices, to work with other organizations as necessary to ensure that weapon program risk assessments include specific attention to software development risks and threats, including those from foreign suppliers.
Grant (2000)	Understand a product's evolutionary track before deciding to modify COTS.
Grant (2000)	Develop a policy prescribing the COTS implementation decision process
Grant (2000)	Core of contractor's team be retained during sustainment of the system
Grant (2000)	Avoid lock-in to a particular supplier
Grant (2000)	Limit technology change to the minimum
Grant (2000)	Consider the impact of upgrades during the initial design phase. Fully automate upgrades.
Grant (2000)	Prepare and implement a policy for acquisition and sustainment of COTS-based systems
Grant (2000)	Involve industry before the operational requirements document (now, the capability development document).
Grant (2000)	Utilize open system architecture
Grant (2000)	Evaluate TCO during source selection.
Grant (2000)	Evaluate the capabilities of the government program office and the contractor – including its experience - to manage a COTS-intensive system
Grant (2000)	Use collocated IPT with contractor
Grant (2000)	Conduct trade-off analyses of all changes using TCO.
Grant (2000)	Evaluate the contractor's processes for assessing, selecting, integrating, supporting and refreshing COTS
Grant (2000)	Use TCO to determine suitability of COTS
Grant (2000)	Assess the contractor's understanding of the marketplace

Source	Recommendation
Grant (2000)	Ensure the system application matches the COTS product functionality
Grant (2000)	Verify that the contractor proposes to use COTS products without modification
Grant (2000)	Participate in consortia to share COTS experiences
Grant (2000)	Increase COTS competency in the workforce. Identify personnel needing the skills, knowledge, skills, and abilities. Develop training and education. Incorporate COTS into DoD education curriculum. Incorporate COTS into certification programs. Make COTS available in Defense Acquisition Deskbook.
Grant (2000)	Conduct annual review of COTS experiences to gather lessons learned.
Grant (2000)	Develop web site repository for COTS experiences – case studies, references, and lessons learned.
Gansler and Lucyshyn (2008)	Leadership needs to mitigate identified challenges to make the DOD "COTS-friendly." Leadership needs to address the organizational culture to embrace COTS products.
GAO/AMID-00-270	Define software security requirements. Based on defined software security requirements, require program managers to collect and maintain information on software suppliers. Require the Office of the Assistant Secretary of Defense for Networks and Information Integration and the Office of the Undersecretary of Defense for Acquisition Technology and Logistics, as part of their role to review, oversee, and formulate security and acquisition practices, to work with other organizations as necessary to ensure that weapon program risk assessments include specific attention to software development risks and threats, including those from foreign suppliers.
Ford and Dillard (2009)	To manage RCIP implementation risk, concerning the development processes, standardize continuous processes and add rigor for sustainability.
Ford and Dillard (2009)	To manage RCIP implementation risk, concerning the innovation sources, (1) adapt continuous processes into a mixture of off-the-shelf and new development solutions, and (2) Implement EA "only mature-enough" strategy.
Ford and Dillard (2009)	To manage RCIP implementation risk, concerning the product system modularity, operationalize modular configuration management for large-scale acquisition with focus on integration.
Ford and Dillard (2009)	To manage RCIP implementation risk, concerning the buyer-supplier relationships, Formalize open, transparent, objective, and repetitive competition processes and organizations.
Ford and Dillard (2009)	To manage RCIP implementation risk, adjust the scope with possible flexibility in costs. Improve user-acquisition coordination to facilitate scope flexibility, and operationalize ARCI management of

Source	Recommendation
	solution acquisition to make RCIP responsive to warfighter priorities.
Rendon (2007)	Program offices managing a MOSA-based program should conduct extensive market research and attend industry conferences to achieve the necessary amount of contractor involvement.
Rendon (2007)	Use a best-value contracting strategy that emphasizes technical performance for MOSA and COTS-based systems. This should be done via evaluation criteria.
GAO (2006)	USAF should collect "information that would allow evaluating the extent of cost savings, increased access to commercial markets, and greater access to nontraditional contractors."
GAO (2006)	USAF should "limit the acquisition of commercial products and services in sole-source environments." "In the cases where it is necessary to award sole-source, the Secretary should collect the information necessary to evaluate the benefit(s) of awarding commercial verses a noncommercial contract."
DODIG (2006)	The Under Secretary of Defense for Acquisition, Technology, and Logistics should: (1). "Propose a legislative change to amend Section 2306a (b), title 10, United States Code to state that the commercial item exception to submission of certified cost or pricing data shall only apply for the acquisition of commercial items that are sold in substantial quantities to the general public. (2). Include commercial item determinations in the contracting file.
DOD (2009)	"DOD should adopt effective and efficient acquisition strategies that utilize COTS/GOTS, as well as commercial- or foreign-derivative systems and practices to satisfy mission needs, and to realize the speed of deployment and low cost needed for future military objectives."
DOD (2009)	"In procurements that involve commercial systems, DOD program management should have proven commercial leadership experience and should ensure leadership experience, domain expertise, and adequate manpower in both government and industry teams."
DOD (2009)	"DOD should form a Rapid Fielding Agency, focused on guiding prototype development (rather than basic or applied research) and fielding capabilities in less than two years."
DOD (2009)	"DOD program management should facilitate full vertical and horizontal communication and visibility, both during the procurement cycle and after the contract is awarded."
DOD (2009)	"DOD agencies should negotiate and contribute to DOD-wide licenses for commercial engineering standards, rather than requiring individual offices or services to purchase separate licenses."
DOD (2009)	"Leadership is required to remove the barriers to rapid and affordable application of COTS/GOTS and commercial- or foreign-derivative products to military needs."

Research Types, Contexts, and Methods

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

Table 8 shows the data collection methods and data analysis methods employed. Most research relied upon archival data. However, a significant amount of research collected data via interviews. Some data were derived from observations, and very little empirical data came from surveys. In one article, it was not possible to discern the data collection method used.

Table 8. Research Methods Used

Data Collection and Data Analysis Methods	Number of Publications
Data Collection Methods	
Survey	4
Observation	7
Interview	10
Archival	13
Unknown	1
Data Analysis Methods	
Case Study	16
Literature Review	5
Grounded Theory	2
Multi-variate Data Analysis	4
Simulation	1
Optimization Modeling	1
Mathematical Model	1
Experiment	2
Unknown	3

Table 9 displays the various publications from which COTS product usage literature was found. Publications varied from peer-reviewed journals, trade publications, and conference proceedings. Table 9 lists the 17 publications.

Table 9. COTS Publications

Journals & Trade Publications	Conference/workshops
COTS Journal: Journal of Military Electronics & Computing	ACM SIGSOFT symposium on Component Based Software Engineering
Control Engineering Practice	Acquisition Research Syposium Proceedings
The Journal of Systems and Software	COTScon conferences, Military Aerospace & Electronics
Information and Software Technology	SEI International Conference on COTS-Based Software Systems
IT Professional Magazine	
Systems Engineering	
IEEE Software	
Engineering Management Journal	
Military & Aerospace Electronics	
Journal of Public Procurement	
Project Management Journal	
National Defense	
CrossTalk: The Journal of Defense Software Engineering	

Each article reviewed was categorized by type of research according to Gregor's (2006) typology (Table 10). Contributions (i.e., articles) were classified as either analyzing, explaining, predicting, explaining and predicting, or design and analysis, as described in the methodology section. Most articles were of the analyzing type (i.e., *what is*) and the design and analysis type (i.e., *how to*).

Table 10. Research Types (Gregor, 2006)

Research Type	Citation Count
Analyzing	18
Explaining	9
Predicting	3
Explaining and Predicting	4
Design and Analysis	18

Additionally, given that the proposed COTS Product Usage Framework herein is built upon the knowledge management framework of Beesley and Cooper (2008), each article reviewed was also classified according to the step in the knowledge process. This classification gives insight into which part of the knowledge management process COTS product usage has been examined - and which steps are underrepresented. Table 11 shows the dominance of disseminated knowledge. Contributions that create new, original knowledge represent 39 percent of the reviewed articles. Notably, few articles address new innovations. However, this is likely due to the small number of published case studies. It is worth mentioning here that, appropriately for a literature review, the unit of analysis of this study is an article, not a case study. It is also worth repeating that some articles are comprised of multiple case studies (i.e., COTS product implementations). As an example, the study by the Air Force Scientific Advisory Board (Grant, 2000) entailed 34 case studies.

Table 11. Knowledge Management Framework Step (Beesley and Cooper, 2008)

Knowledge Management Framework Step	Citation Count
Knowledge Creation	22
Dissemination	27
Knowledge Transfer	0
Knowledge Adoption	0
Innovation	7

Of note, there is little empirical research represented in the literature in this review. Of the 62 sources reviewed, 32 (52 percent) were empirical. Many of the publications lacked a clear research question and a description of the methodology employed, which is consistent with findings from a literature review of COTS-based software (Hauge et al., 2010). Likewise, only 18 of the articles (29 percent) were *scholarly academic*. Articles were considered scholarly academic if they: (1) were published in a peer-reviewed source, (2) provided sufficient evidence of validity and reliability, (3) explained type of data, data source, and data collection method with confidence that bias/error was mitigated, and (4) described an appropriate data analysis method. Many of those publications, 18 of the total 62, were classified as *design and action* (Gregor, 2006), which are prescriptive in nature advising how to do something. It should be noted that while most of the case studies did not demonstrate rigorous, scholarly academic work does not necessarily mean the work was indeed not scholarly academic; it simply means the the information was not reported.

Contexts studied tend to concentrate in the government sector and in the for-profit software sector. This is logical since the government acquires large, expensive, high-profile systems. The attention on software also makes sense; the evolution of the internet, mobile communication, and process automation has intensified in the last two decades.

Theories relied upon were few; only 9 of 56 studies relied upon theory to direct the inquiry. Those theories used included problem oriented engineering, control theory, fuzzy set theory, credibility theory, knowledge management, organizational learning, organizational behavior, technology acceptance model, transaction cost economics, and the information systems success model.

In order to explore associations between scholarly academic research and other characteristics of the studies, five chi squared tests of independence were run on counts of occurrences. First, an association between research type and scholarly academic research was explored. The chi squared test was significant ($\chi^2 = 12.11$; $p<.05$). Examining the crosstabs table (Figure 3), the difference between expected counts and observed counts can be detected in the category of design and action research (i.e., prescriptive, how to). The count of design and action research that is also scholarly academic was substantially lower than that expected, and the inverse was true.

Figure 3. Research Type and Scholarly Academic Crosstabs

Research Type * Scholarly Academic Crosstabulation

			Scholarly Academic		Total
			.00	Yes	
Research Type	Analyzing	Count	10	8	18
		Expected Count	11.8	6.2	18.0
		% within Research Type	55.6%	44.4%	100.0%
		% within Scholarly Academic	29.4%	44.4%	34.6%
		% of Total	19.2%	15.4%	34.6%
	Explaining	Count	5	4	9
		Expected Count	5.9	3.1	9.0
		% within Research Type	55.6%	44.4%	100.0%
		% within Scholarly Academic	14.7%	22.2%	17.3%
		% of Total	9.6%	7.7%	17.3%
	Predicting	Count	1	2	3
		Expected Count	2.0	1.0	3.0
		% within Research Type	33.3%	66.7%	100.0%
		% within Scholarly Academic	2.9%	11.1%	5.8%
		% of Total	1.9%	3.8%	5.8%
	Explaining & Predicting	Count	1	3	4
		Expected Count	2.6	1.4	4.0
		% within Research Type	25.0%	75.0%	100.0%
		% within Scholarly Academic	2.9%	16.7%	7.7%
		% of Total	1.9%	5.8%	7.7%
	Design & Action	Count	17	1	18
		Expected Count	11.8	6.2	18.0
		% within Research Type	94.4%	5.6%	100.0%
		% within Scholarly Academic	50.0%	5.6%	34.6%
		% of Total	32.7%	1.9%	34.6%
Total		Count	34	18	52
		Expected Count	34.0	18.0	52.0
		% within Research Type	65.4%	34.6%	100.0%
		% within Scholarly Academic	100.0%	100.0%	100.0%
		% of Total	65.4%	34.6%	100.0%

Next, an association between knowledge management step and scholarly academic research was explored. The chi squared test was significant ($\chi^2 = 15.13$; $p<.01$). Examining the crosstabs table (Figure 4), the difference between expected counts and observed counts can be detected in the dissemination step. The count of dissemination that is also scholarly academic was substantially lower than that expected, and the inverse was true. Comforting was the result that many more knowledge creation articles than expected were scholarly academic.

Figure 4. Knowledge Management Step and Scholarly Academic Crosstabs

KM Process Step * Scholarly Academic Crosstabulation

			Scholarly Academic		
			.00	Yes	Total
KM Process Step	Knowledge Creation	Count	8	14	22
		Expected Count	14.4	7.6	22.0
		% within KM Process Step	36.4%	63.6%	100.0%
		% within Scholarly Academic	23.5%	77.8%	42.3%
		% of Total	15.4%	26.9%	42.3%
	Dissemination	Count	21	2	23
		Expected Count	15.0	8.0	23.0
		% within KM Process Step	91.3%	8.7%	100.0%
		% within Scholarly Academic	61.8%	11.1%	44.2%
		% of Total	40.4%	3.8%	44.2%
	Innovation	Count	5	2	7
		Expected Count	4.6	2.4	7.0
		% within KM Process Step	71.4%	28.6%	100.0%
		% within Scholarly Academic	14.7%	11.1%	13.5%
		% of Total	9.6%	3.8%	13.5%
Total		Count	34	18	52
		Expected Count	34.0	18.0	52.0
		% within KM Process Step	65.4%	34.6%	100.0%
		% within Scholarly Academic	100.0%	100.0%	100.0%
		% of Total	65.4%	34.6%	100.0%

An association between data analysis method and scholarly academic research was then explored. The chi squared test was significant ($\chi^2 = 17.99$; $p < .05$). Examining the crosstabs table (Figure 5), the difference between expected counts and observed counts can be detected in the articles employing a case study method. The count of case studies that are also scholarly academic was substantially lower than that expected, and the inverse was true. The opposite was also true for literature reviews; the number of literature reviews that were scholarly academic was greater than that expected. There was no appreciable differences between actual counts and expected counts in the other categories of research methods.

Figure 5. Methodology and Scholarly Academic Crosstabs

Data Analysis Method * Scholarly Academic Crosstabulation

			Scholarly Academic		
			.00	Yes	Total
Data Analysis Method	Case Study	Count	12	4	16
		Expected Count	7.8	8.2	16.0
		% within Data Analysis Method	75.0%	25.0%	100.0%
		% within Scholarly Academic	70.6%	22.2%	45.7%
		% of Total	34.3%	11.4%	45.7%
	Lit. Review	Count	0	5	5
		Expected Count	2.4	2.6	5.0
		% within Data Analysis Method	0.0%	100.0%	100.0%
		% within Scholarly Academic	0.0%	27.8%	14.3%
		% of Total	0.0%	14.3%	14.3%
	Grounded Theory	Count	0	2	2
		Expected Count	1.0	1.0	2.0
		% within Data Analysis Method	0.0%	100.0%	100.0%
		% within Scholarly Academic	0.0%	11.1%	5.7%
		% of Total	0.0%	5.7%	5.7%
	Multivariate Analysis	Count	1	3	4
		Expected Count	1.9	2.1	4.0
		% within Data Analysis Method	25.0%	75.0%	100.0%
		% within Scholarly Academic	5.9%	16.7%	11.4%
		% of Total	2.9%	8.6%	11.4%
	Simulation	Count	0	1	1
		Expected Count	.5	.5	1.0
		% within Data Analysis Method	0.0%	100.0%	100.0%
		% within Scholarly Academic	0.0%	5.6%	2.9%
		% of Total	0.0%	2.9%	2.9%
	Optimization	Count	0	1	1
		Expected Count	.5	.5	1.0
		% within Data Analysis Method	0.0%	100.0%	100.0%
		% within Scholarly Academic	0.0%	5.6%	2.9%
		% of Total	0.0%	2.9%	2.9%
	Mathematical	Count	0	1	1
		Expected Count	.5	.5	1.0
		% within Data Analysis Method	0.0%	100.0%	100.0%
		% within Scholarly Academic	0.0%	5.6%	2.9%
		% of Total	0.0%	2.9%	2.9%
	Experiment	Count	1	1	2
		Expected Count	1.0	1.0	2.0
		% within Data Analysis Method	50.0%	50.0%	100.0%
		% within Scholarly Academic	5.9%	5.6%	5.7%
		% of Total	2.9%	2.9%	5.7%
	Unknown	Count	3	0	3
		Expected Count	1.5	1.5	3.0
		% within Data Analysis Method	100.0%	0.0%	100.0%
		% within Scholarly Academic	17.6%	0.0%	8.6%
		% of Total	8.6%	0.0%	8.6%
Total		Count	17	18	35
		Expected Count	17.0	18.0	35.0
		% within Data Analysis Method	48.6%	51.4%	100.0%
		% within Scholarly Academic	100.0%	100.0%	100.0%
		% of Total	48.6%	51.4%	100.0%

Next, an association between empirical/conceptual and scholarly academic research was explored. The chi squared test was significant ($\chi^2 = 8.70$; $p<.01$). Examining the crosstabs table (Figure 6), the difference between expected counts and observed counts can be detected in the articles relying on empirical data. The count of empirical studies that are also scholarly academic was substantially higher than that expected, and the inverse was true. The number of those that were conceptual and scholarly academic was lower than expected.

Figure 6. Empirical/Conceptual and Scholarly Academic Crosstabs

Empirical v. Conceptual * Scholarly Academic Crosstabulation

			Scholarly Academic		
			.00	Yes	Total
Empirical v. Conceptual	.00	Count	18	2	20
		Expected Count	13.1	6.9	20.0
		% within Empirical v. Conceptual	90.0%	10.0%	100.0%
		% within Scholarly Academic	52.9%	11.1%	38.5%
		% of Total	34.6%	3.8%	38.5%
	Empirical	Count	16	16	32
		Expected Count	20.9	11.1	32.0
		% within Empirical v. Conceptual	50.0%	50.0%	100.0%
		% within Scholarly Academic	47.1%	88.9%	61.5%
		% of Total	30.8%	30.8%	61.5%
Total		Count	34	18	52
		Expected Count	34.0	18.0	52.0
		% within Empirical v. Conceptual	65.4%	34.6%	100.0%
		% within Scholarly Academic	100.0%	100.0%	100.0%
		% of Total	65.4%	34.6%	100.0%

Next, an association between theory use and scholarly academic research was explored. The chi squared test was significant ($\chi^2 = 13.33$; $p < .01$). Examining the crosstabs table (Figure 7), the difference between expected counts and observed counts can be detected in the articles that used theory as justification or grounding for the research. The count of theory-grounded studies that are also scholarly academic was substantially higher than that expected, and the inverse was true. The number of those that were atheoretical and scholarly academic was lower than expected.

Figure 7. Theory Used and Scholarly Academic Crosstabs

Theory Used * Scholarly Academic Crosstabulation

			Scholarly Academic		
			.00	Yes	Total
Theory Used	.00	Count	31	10	41
		Expected Count	26.2	14.8	41.0
		% within Theory Used	75.6%	24.4%	100.0%
		% within Scholarly Academic	96.9%	55.6%	82.0%
		% of Total	62.0%	20.0%	82.0%
	Yes	Count	1	8	9
		Expected Count	5.8	3.2	9.0
		% within Theory Used	11.1%	88.9%	100.0%
		% within Scholarly Academic	3.1%	44.4%	18.0%
		% of Total	2.0%	16.0%	18.0%
Total		Count	32	18	50
		Expected Count	32.0	18.0	50.0
		% within Theory Used	64.0%	36.0%	100.0%
		% within Scholarly Academic	100.0%	100.0%	100.0%
		% of Total	64.0%	36.0%	100.0%

THIS PAGE INTENTIONALLY LEFT BLANK

Discussion

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. Indeed, a search of the government's Federal Business Opportunities portal yielded 17,874 active solicitations using the keyword "commercial off the shelf." This 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 help manage COTS product implementations ex post. The follow section addresses the managerial implications associated with the findings, identifies limitations of the study, and charts future research directions.

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 unlikely to be welcomed by program managers who spend their days anticipating and defending against risks. What has 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 numbers 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 (a.k.a., 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. Figure 8 shows the quantity of source hits resulting from the search term "commercial off the shelf" in the ProQuest ABI/Inform Global database. 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* (Figure 9). The quantity of COTS-related patents also seems to have peeked 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.

Figure 8. COTS Publications Over Time (ProQuest ABI/Inform Global)

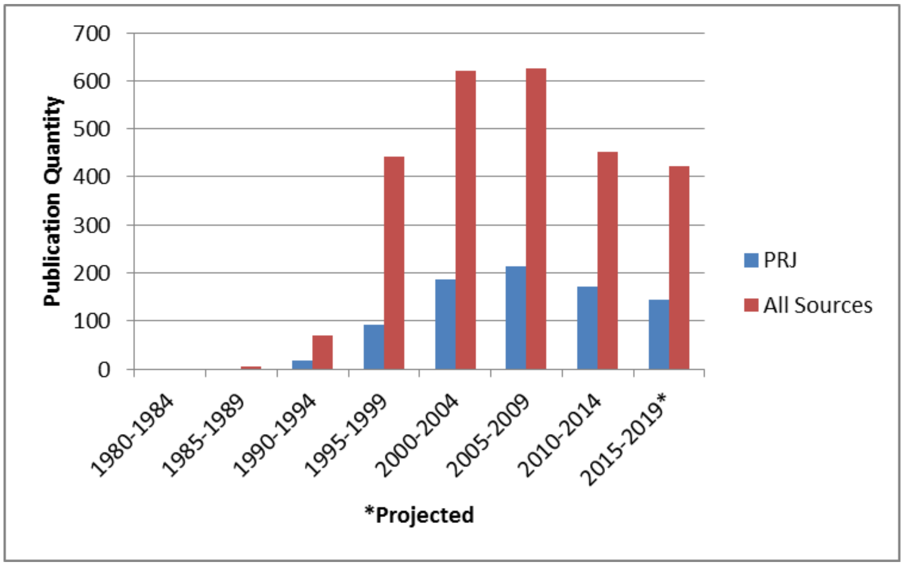
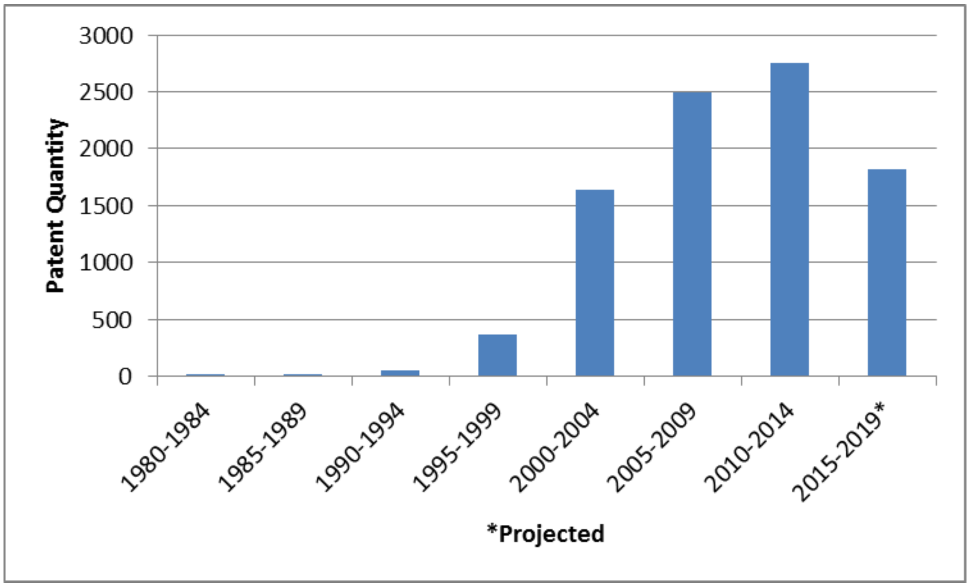


Figure 9. COTS-Related U.S. Patents Over Time



“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 and 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 (Rentsch, 2014). Security of COTS-based systems is (DODIG, 2016a) and will continue to be a serious issue. And, the DFARS requirements for counterfeit electronic part detection and avoidance (DFARS 252.246-7007) that flows 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 ten components. Then, imagine that each of those sets of ten 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 lifecycles 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 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 prescribed by the FAR. Under the Defense Innovation Unit Experimental (DIUx) program (https://diux.mil/), 25 OTAs have been awarded valued at $48.4M (DIUx, 2017). This program is drawing private investment from venture capitalists, and is drawing in 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 for which soldiers have lauded as life critical but was refused by the Army somewhat arbitrarily (U.S. COFC, 2016). Thus, antecedent factors of COTS product adoption beyond functional capability deserve special attention.

The relevant literatures surrounding COTS implementations is severely lacking in theoretical grounding (Hall and Rapanotti, 2016). This void can stymy 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 phenomenon. 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 and 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, 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 and 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" (Horowitz and Lambert, 2006, 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 (Appendix B) 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 and 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 to ensure 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 could be conducted to quantify the extent of COTS implementation, and quantitatively validate the positive and negative antecedents to COTS implementation performance. Perhaps the Government Accountability Office is best suited to conduct this study. The researching organization should deploy a data call for all current programs' usage of COTS. USSOCOM should be included since 88 percent of their requirements entail COTS products (GAO, 2007). Next, from this population, a statistically representative sample should be drawn and sampled – with each Services' Senior Acquisition Executive's study endorsement coupled with DOD-wide survey approval.

(7) The DOD should not establish quotas for COTS implemenations. Quotas have, in the past, manifested in percentage goals (i.e., COTS products have to constitute a certain percentage of a system). Extrensic 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 implentation effectiveness to the contractor performance assessment reporting (CPAR). This follows recommendations by Rendon (2007). It should motive 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) 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 valueable 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 (Appendix B). 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.

Study Limitations

This research is not without limitations. Findings may be confounded by shortcomings that are inherent in literature reviews. According to Wolfe (1986), these limitations include: ''the selective inclusion of studies, differential subjective weighting of studies in the interpretation of findings, misleading interpretations of study findings, the failure to examine characteristics of the studies as potential explanations for disparate or consistent results across studies, and the failure to examine moderating variables'' (Wolfe, 1986, p. 10).

The findings herein are limited to cases that have previously been studied, published, and made publicly available. Many COTS product implementations have not been made public because they are leading-edge classified programs. Thus, these types of programs are not represented in the data and analysis.

The number of published DOD case studies of COTS product implementations is small, and the number of rigorous, scholarly, published DOD case studies is even smaller. Thus, some antecedents to COTS appropriateness, some barriers to successful implementation, and some COTS implementation enablers (i.e., success factors): (1) may not be captured in the study and (2) may not rise to their true level of impact on dependent variables. Antecedents were identified to the extent that a pattern could be discerned. A pattern was considered to exist upon the occurrence of four mentions across different sources. This threshold is admittedly arbitrary; while it reflects a pattern, an argument can be made for different threshold values such as three or five occurrences. The limitation posed by a limited number of rigorous cases was somewhat tempered by the inclusion of non-DOD academic studies of COTS product usage.

Future Research Directions

Scientific rigor would enable the detailed study of moderators. COTS product usage is sufficiently complex that many moderating conditions likely make a difference in program success or failure. For example, there may be meaningful differences in COTS product appropriateness antecedents (and to barriers and enablers) by platform, domain, type of technology, etc. Could it be that there is an appreciable difference in the proposed COTS product framework when integrating a COTS aircraft, for example, than when integrating software or buying a commercial item and using it as-is with no further integration? Research should explore whether there is a taxonomy of COTS products resulting in a meaningful classification of types. If the types are found to differ significantly, policies and procedures should be customized to each type to account for the different risks.

Future research is needed to validate the proposed scale measuring COTS appropriateness. Empirical data is needed to quantitatively assess reliability and validity of the scale. Additionally, while this research asserts no conclusions based on attaining certain threshold levels of COTS appropriateness, future research may be able to do so. For instance, what is the minimum level of appropriateness needed (on the scale of 1-7) before adopting COTS, and does this minimum level differ by COTS type (e.g., pure software versus a hardware and software-based system)?

Over the years, several recommendations for the implementation and management of COTS products usage have been made (Table 7). Future research could explore the extent to which previous recommendations for the management of COTS product integration and use have been implemented.

Future research could empirically test the proposed COTS Product Usage Framework for validation. Expounding work could also seek nuances or contingencies (i.e., moderators) to add fidelity to the model. In what situations, for example, does the model hold true? What weakens the model? Do antecedent factors differ by the situation (e.g., industry, technology, application domain, military service, etc.)?

Future research could investigate how for-profit sector industrial developers (e.g., General Electric, John Deere, General Motors, etc.), deal with: (1) the conflict between customers and manufacturer's own motives for custom designs that are protected by IP rights (creating customer lock-ins), and (2) suppliers' IP rights. AT Kearney, in a case study of heavy equipment industry that has a similar structure and scale to that of the DOD, suggested the DOD adopt several proven practices for its acquisition and supply chain predicaments. Among them were reducing production and development time, streamlining the adoption of COTS solutions, and adopting open system architectures (Garber et al., 2011). These recommendations seemed to be embedded in the DOD's Better Buying Power initiatives. However, more fidelity into how to implement these ideas is needed.

Conclusion

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. As such, there has been recent renewed activity in leveraging the potential cycle time savings, performance improvements, and lifecycle cost reduction offered by implementing COTS products into defense acquisition.

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.

References

American Bureau of Shipping (ABS). (2007). “ABS Guide for Building and Classing Naval Vessels.” American Bureau of Shipping: Houston, Texas.

Alcide, D. W. (2006). “Transformation Of Organizational Legacy Logistics Systems And Facilitating An Integrated Lean Enterprise: A Case Study Within The United States Army.” Dissertation, Capella University.

Amadeo, K. (2017). “FY 2017 Federal Budget: Obama,Trump And Enacted Budgets.” The Balance, Attained online on 30 July 2017 at: https://www.thebalance.com/how-trump-amended-obama-budget-4128986.

Ashworth, R., Boyne, G.A., and Walker, R.M. (2002). “Regulatory problems In The Public Sector: Theories and cases.” *The Policy Press*, 30(2), 195–211.

Badampudi, D., Wohlin, C., and Petersen, K. (2016). “Software Component Decision-making: In-house, OSS, COTS or Outsourcing - A systematic Literature Review.” *The Journal of Systems and Software*, 121, 105-124.

Baker, B. (2002). “The Fall Of The Firefly: An Assessment Of A Failed Project Strategy.” *Project Management Journal*, 33(3), 53-57.

Baldwin, Kristen. (2007). “DoD Software Engineering and System Assurance New Organization – New Vision.” Presentation by UOSD (AT&L), Defense Software Strategy Summit. Retreived online 15 July 2017 at: http://csse.usc.edu/events/2007/arr/presentations/baldwin.ppt.

Baron, S. J. F. (2004). “Keeping Pace: Organizational Barriers To Commercial Product Use In DOD.” *Journal of Public Procurement*, 4(2), 182-209.

Beesley, L. G., and Cooper, C. (2008). “Defining Dnowledge Management (KM) Activities: Towards Consensus.” *Journal of Knowledge Management*, 12(3), 48-62.

Bhatt, G. D. (2001). “Knowledge Management In Organizations: Examining The Interaction Between Technologies, Techniques, And People.” *Journal of Knowledge Management*, 5(1), 68-75.

Bjornson, F.O. and Dingsoyr, T. (2008). “Knowledge Management In Software Engineering: A Systematic Review Of Studied Concepts, Findings And Research Methods Used.” *Information and Software Technology*, 50(11), 1055–1068.

Boudreau, M.W. (2006). “Acoustic Rapid COTS Insertion—Case Study.” NPS-PM-06-041. Acquisition Research Program, Monterey, CA.

Bovio, E., Cecchi, D. and Baralli, F. (2006). “Autonomous Underwater Vehicles For Scientific And Naval Operations.” *Annual Reviews In Control*, 30, 117-130.

Branstetter, J. (2005). “The Darleen Druyun Debacle: Procurement, Power, And Corruption.” Thesis, The George Washington University Law School.

Brill, S. (2017). “Donald Trump, Palantir, And The Crazy Battle To Clean Up A Multi-Billion-Dollar Military Procurement Swamp.” *Fortune*, April, 78-90.

Cameron, A., Stumptner, M., Nandagopal, N., Mayer, W., and Mansell, T. (2015). “Rule-based Peer-To-Peer Framework For Decentralised Real-Time Service Oriented Architectures.” *Science Of Computer Programming*, 97, 202-234.

Carney, D.J. and Oberndorf, P.A. (n.d.). “The Commandments of COTS: Still in Search of the Promised Land.” Software Engineering Institute, Carnegie Mellon University: Pittsburgh, PA, retreived online 30 June 2017 at: https://acc.dau.mil/CommunityBrowser.aspx?id=24403&lang=en-US

Carter, A.B. (2010). “Better Buying Power: Guidance For Obtaining Greater Efficiency And Productivity In Defense Spending.” Office of the Under Secretary of Defense for Acquisition and Technology Memorandum, 14 Sep 10.

Carter, A.B.. (2010). “Implementation Directive For Better Buying Power - Obtaining Greater Efficiency And Productivity in Defense Spending.” Office of the Under Secretary of Defense for Acquisition and Technology Memorandum, 3 Nov 10.

Carter. A.B. (2011). “Policy For Defense Business Systems (DBS).” Office of the Under Secretary of Defense for Acquisition and Technology Directive-Type Memorandum 11-009.

Cassidy, S. and Stanton, P. (2017). “Cybersecurity Requirements Clarified.” *National Defense*, Retrieve online 17 July 2017 at: http://www.nationaldefensemagazine.org/articles/2017/3/21/cybersecurity-requirements-clarified.

Cechich, A., and Piattini, M. (2007). “Early Detection Of COTS Component Functional Suitability.” *Information and Software Technology*, 49(2), 108.

Charette, R.N. (2013). “The U.S. Air Force Explains its $1 Billion ECSS Bonfire.” IEEE Spectrum, 6 December 2013, attained online 3 July 2017 at: http://spectrum.ieee.org/riskfactor/aerospace/military/the-us-air-force-explains-its-billion-ecss-bonfire.

Clark, J., Clarke, C., De Panfilis, S., Granatella, G., Predonzani, P., Sillitti, A., Succi, G., and Vernazza, T. (2004). “Selecting Components In Large COTS Repositories.” *The Journal of Systems and Software*, 73(2), 323-331.

Cohen, W.L. and Levinthal, D.A. (1990). “Absorptive Capacity: A New Perspective On Learning And Innovation.” *Administrative Science Quarterly* 35(1), 128–152.

ComponentSource. (2017). Attained online 7 July 2017 from: https://www.componentsource.com/

Couts, C. T., and Gerdes, P. F. (2010). "Integrating COTS Software: Lessons From A Large Healthcare Organization." *IT Professional Magazine*, 12(2), 50-58.

Creswell, J.W. (2003). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches,* 2nd Ed. Sage Publications: Thousand Oaks, CA.

Curry, J., Price, T., and Sabin, P. (2016). "Commercial-Off-the-Shelf-Technology in UK Military Training*." Simulation & Gaming*, 47(1), 7-30.

Davis, F.D. (1989). "Perceived Usefulness, Perceived Ease Of Use, And User Acceptance Of Information Technology", *MIS Quarterly*, 13(3), 319-39.

Defee, C. C., Williams, B., Randall, W. S., and Thomas, R. (2010). "An Inventory Of Theory In Logistics And SCM Research." *International Journal of Logistics Management*, 21(3), 404-489.

Defense Innovation Unit Experimental (DIUx). (2017). "DIUx Quarterly Results - Q2 2017." April 20, 2017, retreived online 15 July 2017 at: https://diux.mil/library.

Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology. (2003). "Department of Defense Directive 5000.01, The Defense Acquisition System." Washington, DC: Author.

Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology. (2015). "DOD Instruction 5000.02, Operation of the Defense Acquisition System." Washington, DC: Author.

Department of Defense (DOD). (2012). "DOD Instruction 5200.44, Protection of Mission Critical Functions To Achieve Trusted Systems And Networks (TSN)." Washington, DC: Author.

Department of Defense (DOD). (2013). "DoD Open Systems Architecture Contract Guidebook for Program Managers, v.1.1." Washington, DC: Author.

Department of Defense (DOD). (1993). "DoD 5010.12M, Procedures for the Acquisition and Management of Technical Data." Washington, DC: Author.

Department of Defense (DOD). Defense Federal Acquisition Regulation Supplement (DFARS). Washington, DC: Author.

Department of Defense (DOD). (2000). "Defense Acquisition Guidebook, Chapter 3, Systems Engineering." Washington, DC: Author.

Department of Defense (DOD). (2005). "DoD Enterprise Architecture Technical Reference Model v0.04," 20 August 2005. Washington, DC: Author.

Department of Defense (DOD). (2007). "DoD Department of Defense Global Information Grid Architectural Vision." June 2007. Washington, DC: Author.

Department of Defense (DOD). (2007). "Department of Defense Net-Centric Services Strategy." March 2007. Washington, DC: Author.

Department of Defense (DOD). (2009). "Report of the Defense Science Board Task Force on Integrating Commercial Systems Into the DoD, Effectively and Efficiently – Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems." Washington, DC: Author.

Department of Defense, Office of the Secretary of Defense. (2000). "Commercial Item Acquisition: Considerations And Lessons Learned." retreived online 18 July 2017 at: www.acq.osd.mil/dpap/Docs/cotsreport.pdf.

Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology. (2001). "Commercial Acquisitions." Washington, DC: Author.

Department of Defense Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (DOD AT&L). (1996). "Buying Commercial and Non-development Items, Handbook S-2." Washington, DC: Author.

Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (DOD AT&L). (2000). "Commercial Item Acquisition: Considerations and Lessons Learned." Memorandum of July 14, 2000. Washington, DC: Author.

Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (DOD AT&L). (2013). "Open Systems Architecture Contract Guidebook For Program Managers." version 1.1. Washington, DC: Author.

Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. (2017). "Commercial Solutions Opening: Innovation in Contracting." DAU Hot Topic Forum, 17 May 17.

Department of Defense Inspector General. (DODIG). (2004a). "Acquisition of the Boeing KC-767A Tanker Aircraft." D-2004-064. Arlington, VA: Author.

Department of Defense Inspector General. (DODIG). (2004b). "Contracting for and Performance of the C-130J Aircraft." D-2004-102. Arlington, VA: Author.

Department of Defense Inspector General.(DODIG). (2006a). "Commercial Contracting for the Acquisition of Defense Systems." D-2006-115. Arlington, VA: Author.

Department of Defense Inspector General. (DODIG). (2006b). "Acquisition of the Joint Primary Aircraft Training System." D-2006-075. Arlington, VA: Author.

Department of Defense Inspector General. (DODIG). (2016a). "DOD Needs to Require Performance of Software Assurance Countermeasures During Major Weapon System Acquisitions." DODIG-2016-082. Arlington, VA: Author.

Department of Defense Inspector General. (DODIG). (2016b). "Audit of the DoD Healthcare Management System Modernization Program." DODIG-2016-094. Arlington, VA: Author.

Department of the Navy (DON). (2004). “Naval Open Architecture Scope and Responsibilities.” Memorandum of 5 August 2004. Washington, DC: Author.

Department of the Navy (DON). Navy Marine Corps Acquisition Regulation Supplement (NMCARS). Washington, DC: Author.

Department of the Navy. (DON). (2013). “OPNAV Instruction 1500.76C, Naval Training Systems Requirements, Acquisition, And Management.” Washington, DC: Author.

Department of the Navy, Office of the Assistant Secretary of the Navy (Research, Development and Acquisition). (2008). “Acquisition of Naval Software Intensive Systems, v. 1.0.” September 2008. Washington, DC: Author.

Department of the Navy, Office of the Secretary of the Navy. (2009). “SECNAVINSTR 5230.15, Information Management/Information Technology Policy For Fielding Of Commercial Off The Shelf Software.” Washington, DC: Author.

Department of the Navy, Office of the Secretary of the Navy. (2011). “SECNAV Instruction 5000.2E, Department Of The Navy Implementation And Operation Of The Defense Acquisition System And The Joint Capabilities Integration And Development System.” Washington, DC: Author.

Department of the Navy, Office of the Secretary of the Navy. (2016). “SECNAV Instruction 5000.42 Accelerated Acquisition For The Rapid Development, Demonstration And Fielding Of Capability.” Washington, DC: Author.

Department of the Navy, Office of the Secretary of the Navy. (2009). “SECNAV Instruction 5230.15, Information Management/Information Technology Policy For Fielding Of Commercial Off The Shelf Software.” Washington, DC: Author.

Department of the Navy, Office of the Secretary of the Navy. (2009). “SECNAV Instruction 5230.14, Information Technology Portfolio Management Implementation.” Washington, DC: Author.

Desouza, K. C., Chattaraj, A. and Kraft, G. (2003). “Supply Chain Perspectives To Knowledge Management: Research Propositions.” *Journal of Knowledge Management*, 7(3), 129-138.

Erwin, S.I. (2016). “Pentagon Taking a More Serious Look at Off-the-Shelf Technology.” *National Defense*, Retrieve online 17 July 2017 at: http://www.nationaldefensemagazine.org/articles/2016/12/12/pentagon-taking-a-more-serious-look-at-off-the-shelf-technology.

Federal Acquisition Regulation, 48 C.F.R. § 3.502-1 (2017).

Finkenstadt, D., Hawkins, T., and Hosey, W. (2014), “Growing Contracting Competency: Market Intelligence Cells.” *Contract Management*, (November), 20-31.

Ford, D.N. and Dillard, J.T. (2009). "Modeling Open Architecture And Evolutionary Acquisition: Implementation Lessons From The Arci Program For The Rapid Capability Insertion Process." NPS-AM-09-043. *Proceedings of the 6th Annual Acquisition Research Symposium*, Vol II., April 22, 2009, Monterey, CA.

Gansler, J.S. and Lucyshyn, W. (2008). "Commercial-Off-The-Shelf (Cots): Doing It Right." UMD-AM-08-129. Acquisition Resarch Program: Monterey, CA.

Garber, R., Willen, B., Heckler, A., and Skarda, T. (2011). "Affordability in the U.S. Defense Department: A Better Approach to Dealing With Declining DOD Budgets." AT Kearney: Atlanta, GA.

Gartner, Inc. (2014). "Gartner Says Worldwide Software Market Grew 4.8 Percent In 2013," attained online July 5, 2017 at: http://www.gartner.com/newsroom/id/2696317.

GlobalPlatform. (2003). "Case Study: Common Access Cards - Expanding the Functionality of ID Cards for the US Department of Defense." Attained online July 12, 2017 at: www.globalplatform.org/fcs/DOD_Case_Study.pdf .

Google Patents (2017). https://patents.google.com.

Government Accountability Office (GAO). (2000). "Selected Agencies' Use of Commercial Off-the-Shelf Software for Human Resources Functions." (GAO/AIMD-00-270). Washington, DC: Author.

Government Accountability Office (GAO). (2004). "Knowledge of Software Suppliers Needed to Manage Risks." (GAO-04-678). Washington, DC: Author.

Government Accountability Office (GAO). (2005). "DOD Systems Modernization: Management of Integrated Military Human Capital Program Needs Additional Improvements." (GAO-05-189). Washington, DC: Author.

Government Accountability Office (GAO). (2006). "Efforts Needed to Address Air Force Commercial Acquisition Risk." (GAO-06-995). Washington, DC: Author.

Government Accountability Office (GAO). (2007). "Defense Acquisitions: An Analysis of the Special Operations Command's Management of Weapon System Programs." (GAO-07-620). Washington, DC: Author.

Government Accountability Office (GAO). (2013). "Satellite Control: Long-Term Planning and Adoption of Commercial Practices Could Improve DOD's Operations." (GAO-13-315). Washington, DC: Author.

Government Accountability Office (GAO). (2015). "DOD Business Systems Modernization: Additional Action Needed to Achieve Intended Outcomes." (GAO-15-627). Washington, DC: Author.

Government Accountability Office (GAO). (2016). "OMB and Agencies Need to Focus Continued Attention on Implementing Reform Law." (GAO-16-672T). Washington, DC: Author.

Government Accountability Office (GAO). (2017a). “Actions Needed to Address Five Key Mission Challenges.” (GAO-17-369). Washington, DC: Author.

Government Accountability Office (GAO). (2017b). “Recent Legislation and DOD Actions Related to Commercial Item Acquisitions.” (GAO-17-645). Washington, DC: Author.

Grady, C.M. (2016). “Commercial Items and Determination of Reasonableness of Price for Commercial Items.” Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, Defense Procurement and Acquisition Policy Memorandum, 2 Sep 16.

Grandinetti, R. (2016). “Absorptive Capacity and Knowledge Management in Small and Medium Enterprises.” *Knowledge Management Research & Practice*, 14, 159-168.

Grant, J. (2000). “Ensuring Successful Implementation of Commercial Off-the-Shelf Products (COTS) in Air Force Sysstems.” Defense Systems Management College Press, Ft Belvoir, VA.

Gregor, S. (2006). “The Nature Of Theory In Information Systems.” *MIS Quarterly*, 30(3), 611-642.

Gump, J., Mazzuchi, T., and Sarkani, S. (2017). “An Architecture for Agile Systems Engineering of Secure Commercial Off-the-Shelf Mobile Communications.” *Systems Engineering*, 20(1), 71-91.

Gunter, C., Gunter, E.L., Jackson, M., and Zave, P. (2000). “A Reference Model For Requirements And Specifications. In Requirements Engineering.” *Proceedings. 4th International Conference on. IEEE*, 189.

Guntersdorfer, M. S., and Kay, D. G. (2002). “How Software Patents Can Support COTS Component Business.” *IEEE Software*, 19(3), 78-83.

Hall, J.G. and Rapanotti, L. (2016). “A Design Theory For Software Engineering.” Technical Report TR2016/01. Department of Computing and Communications, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK.

Hambling, D. (2017). “Islamic State’s New Weapon Of Choice: Off-the-Shelf Drones.” Aviation Week, Retrieved online 15 July 2017 at: http://aviationweek.com/defense/islamic-state-s-new-weapon-choice-shelf-drones.

Hansen, M.T., Nohria, N., and Tierney, T. (1999). “What Is Your Strategy For Managing Knowledge?” *Harvard Business Review*, 77(2), 106–116.

Hart, C. (1998). *Doing a Literature Review: Releasing the Social Science Research Imagination*. Sage Publications: London.

Hauge, O. , Ayala, C. , and Conradi, R. (2010). “Adoption Of Open Source Software In Soft- Ware-Intensive Organizations–A Systematic Literature Review.” *Information and Software Technology,* 52(11), 1133–1154.

Hawkins, T. (2016). “Antecedents and Consequences of Supplier Performance Evaluation Efficacy,” WKU-CM-16-150. Acquisition Research Program, Sponsored Report Series, Naval Postgraduate School, Monterey, CA.

Holsapple, C., and Wu, J. (2011). “An Elusive Antecedent of Superior Firm Performance: The Knowledge Management Factor.” *Decision Support Systems*, 52(1): 271–283.

Horowitz, B. M., and Lambert, J. H. (2006). “Assembling Off-the-Shelf Components: "Learn as You Go" Systems Engineering.” *IEEE Transactions On Systems, Man & Cybernetics: Part A*, 36(2), 286-297.

Hurley, R. F., and Hult, G. T. M. (1998). “Innovation, Market Orientation, and Organizational Learning: An Integration and Empirical Examination.” *Journal of Marketing*, 62(3), 42-54.

IBISWorld (2017). “51121 – Software Publishing in the US.” IBISWorld iExpert, May 2017.

IEEE Computer Society. (1990). “IEEE Standard Computer Dictionary: a Compilation of IEEE Computer Glossaries: 610.” New York: IEEE Computer Society.

IEEE Computer Society. (1995). “J-STD-016-1995 Trial-Use Standard for Information Technology - Software Life Cycle Processes - Software Development - Acquirer-Supplier Agreement.” New York: IEEE Computer Society.

Incze, M. (2011). “Lightweight Autonomous Underwater Vehicles (Auvs) Performing Coastal Survey Operations In REP 10A.” *Ocean Dynamics*, 61(11), 1955-1965

Jilani, J.K. (2008). “*Using Cots Components In Software Development*.” AIP Conference Proceedings, 1052(1), American Institute of Physics, 203-208.

Julian, C., Lucy, T., and Farr, J. (2011). “Commercial-Off-The-Shelf Selection Process.” *Engineering Management Journal*, 23(2), 63-71.

Kakar, A.K. (2013). “Feature Selection For Evolutionary Commercial-Off-The-Shelf.” Dissertation. University of Alabama: Tuscaloosa, AL.

Keil, M., and Tiwana, A. (2005). “Beyond Cost: The Drivers Of COTS Application Value.” *IEEE Software*, 22(3), 64-69.

Keller, J. (2015). “COTS Components On The Rise In Communications And Surveillance.” *Military & Aerospace Electronics*, 26(12), 4.

Kendall, F. (2012). “Better Buying Power 2.0: Continuing the Pursuit For Greater Efficiency and Productivity in Defense Spending.” Office of the Under Secretary of Defense for Acquisition and Technology Memorandum, 13 Nov 12.

Kendall, F. (2012). “Implementation Directive for Better Buying Power 2.0: Achieving Greater Efficiency and Productivity in Defense Spending.” Office of the Under Secretary of Defense for Acquisition and Technology Memorandum, 24 Apr 13.

Kendall, F. (2014). “Better Buying Power 3.0.” Office of the Under Secretary of Defense for Acquisition and Technology White Paper, 19 Sep 14.

Kendall, F. (2014). “Implementation Directive for Better Buying Power 3.0: Achieving Dominant Capabilities Through Technical Excellence and Innovation.” Office of the Under Secretary of Defense for Acquisition and Technology Memorandum, 9 Apr 15.

Kendall, F. (2015). “Compendium of Annual Program Manager Assessments for 2015.” Department of Defense (DOD).

Kirtley, R.W. (1979). “Government acquisition of commercial products what is the policy?” NPS Thesis. Naval Postgraduate School: Monterey, CA.

Kohl, R. (2000). “GSAW00 COTS Panel Outbriefing.” COTScon West, Military Aerospace and Electronics. Retrieved online 28 July 2017 at: http://sunset.usc.edu/events/GSAW/gsaw2000/pdf/KohlOutbrief.pdf.

Landi, H., Leventhal, R., and Hagland, M. (2017). “DOD Deploys Cerner EHR System, MHS Genesis, at Fairchild AFB.” Healthcare Informatics. Retreived online 15 July 2017 at: https://www.healthcare-informatics.com/news-item/ehr/dod-deploys-cerner-ehr-system-mhs-genesis-fairchild-afb.

Larezos, M.D. (2008). “Leaders Can Learn From Druyun’s Ethical Lapses And Their Consequences.” U.S. Army War College: Carlisle Barracks, PA.

Leedy, P.D. and Ormrod, J.E. (2005). *Practical Research: Planning and Design*, 8th Ed., Pearson Merrill Prentice Hall: Upper Saddle River, NJ.

Lobur, J. M. (2011). “The Success Of A COTS Caseload Management System In State Government.” *IEEE Software*, 28(2), 10-14.

Lockheed-Martin. (2017). “Next Generation Aegis Ballistic Missile Defense System Successfully Engages Medium Range Ballistic Missile Target.” News Release retrieved 15 July 2017 at: http://news.lockheedmartin.com/2017-02-06-Next-Generation-Aegis-Ballistic-Missile-Defense-System-Successfully-Engages-Medium-Range-Ballistic-Missile-Target .

Lorell, M.A., Payne, L.A., and Mehta, K.R. (2017). “Program Characteristics That Contribute to Cost Growth: A Comparison of Air Force Major Defense Acquisition Programs.” RAND Corporation: Santa Monica, CA.

Luecke, R. and Katz, R. (2003), *Managing Creativity and Innovation*, Harvard Business School Press: Boston, MA.

Maras, J. , Lednicki, L. , Crnkovic, I. (2012). “15 Years Of CBSE Symposium: Impact On The Research Community.” In: *Proceedings of the 15th ACM SIGSOFT symposium on Component Based Software Engineering.* ACM, 61–70.

Mariani, L., and Pezzè, M. (2007). “Dynamic Detection Of COTS Component Incompatibility.” *IEEE Software*, 24(5), 76-85.

Mehlawat, M. K., and Gupta, P. (2015). “Multiobjective Credibilistic Model For COTS Products Selection Of Modular Software Systems Under Uncertainty.” *Applied Intelligence*, 42(2), 353-368.

Miguel, J. G. S., Shank, J. K., and Summers, D. E. (2008). “Leasing As A Strategic Financing Option: The Navy's Maritime Prepositioned Ships Experience.” *Journal of Public Procurement*, 8(2), 149-173.

Miles, M.B. and Huberman, A.M. (1994), *Qualitative Data Analysis*, Sage Publications: Thousand Oaks, CA.

Morisio, M., Seaman, C. B., Basili, V. R., Parra, A. T., Kraft, S.E., and Condon, S.E. (2002). “COTS-based Software Development: Processes And Open Issues.” *The Journal of Systems and Software*, 61(3), 189-199.

Morrow, D. (2010). “No. 20: Integrating COTS: Lessons from Recent Ground Vehicle Acquisitions.” Retrieved online July 12, 2017 at: https://csis-prod.s3.amazonaws.com/s3fs.../100115_DIIG_Current_Issues_n20.pdf , Center For Strategic and International Studies, *Current Issues*, 20.

Naegle, B, and Petross, D. (2010). “P-8A Poseidon Multi-mission Maritime Aircraft (MMA) Software Maintenance Organization Concept Analysis.” NPS-LM-10-006. Naval Postgraduate School. Acquisition Research Program: Monterey, CA.

Nissen, M. E. (2006). *Harnessing Knowledge Dynamics: Principled Organizational Knowing & Learning*. Hershey, PA: IGI Global.

O'Dell, Carla S., C. Jackson Grayson, and Nilly Essaides (1998). *If Only We Knew What We Know: The Transfer Of Internal Knowledge And Best Practice*. Simon and Schuster: New York, NY.

O'Halloran, M., Hall, J. G., and Rapanotti, L. (2017). “Safety Engineering With COTS Components.” *Reliability Engineering & System Safety*, 160, 54-66.

Perry, William. (1994). Letter to Chairman of Joint Chiefs of Staff, et al., 29 June 1994.

Peterson, S., Webber, L., and Rosselli, D. (2013). “Chief Procurement Officer Study: Improving Competitive Advantage Through Procurement Excellence.” IBM Global Business Services: Somers, NY.

Prosnik, G. (2003). “COTS-Based Systems.” Software Acquisition Management (SAM) Executive Seminar, SAM-450. Defense Acquisition University.

Ragab, M. and Arisha, A. (2013). “Knowledge Management And Measurement: A Critical Review.” *Journal of Knowledge Management*, 17(6), 873-901.

Reifer, D. J., Basili, V. R., Boehm, B. W., and Clark, B. (2003). “Eight Lessons Learned During COTS-Based Systems Maintenance.” *IEEE Software*, 20(5), 94-96.

Rendon, R. (2007). “Analysis of Modular Open Systems Approach (MOSA) Implementation in Navy Acquisition Programs.” NPS-AM-07-016. *Proceedings of the 4th Annual Acquisition Research Symposium,* April 30, 2007, Monterey, CA.

Rentsch, J.R. (2014). “Written Testimony, Aerospace Industries Association, June 16, 2014.” Aerospace Industries Association: Arlington, VA.

Riehle, R.D. (2008). “An Engineering Context For Software Engineering.” Dissertation, Naval Postgraduate School: Monterey, CA.

Riposo, J., McKernan, M, and Duran, C.K. (2014). “Prolonged Cycle Times and Schedule Growth in Defense Acquisition: A Literature Review.” RAND Corporation: Santa Monica, CA.

Rogers, F.F.C. (1983). *The Nature Of Engineering: A Philosophy Of Technology*. Macmillan Press: London.

Rosa, W., Packard, T., Krupanand, A., Bilbro, J. W., and Hodal, M. M. (2013). “COTS Integration And Estimation For ERP.” *The Journal of Systems and Software*, 86(2), 538.

Scacchi, W. and Alspaugh, T. (2016). “Achieving Better Buying Power for Mobile Open Architecture Software Systems Through Diverse Acquisition Scenarios.” SYM-AM-16-033. *Proceedings of the 13th Annual Acquisition Research Symposium, Vol I.*, April 30, 2016, Monterey, CA.

Software Engineering Institute (SEI). (2016). “RFP Patterns and Techniques for Successful Agile Contracting.” Special Report CMU/SEI-2016-SR-025. Carnegie Mellon University: Pittsburg, PA.

Stein, F. (2006). “TSM-Satcom Update Ka-Band Satellite Transmit And Receive System AN-GSC-70(V).” *Army Communicator*, 31(1), 31-33.

Tadjdeh, Y. (2017). “Marine Corps Investing in Light Vehicles To Take the Load Off Troops’ Shoulders,” National Defense, Retrieved online 16 July 2017 at: http://www.nationaldefensemagazine.org/articles/2017/4/3/marine-corps-investing-in-light-vehicles-to-take-the-load-off-troops-shoulders.

Thomas, G. A., and Jajodia, S. (2004). “Commercial- Off-The- Shelf Enterprise Resource Planning Software Implementations In The Public Sector: Practical Approaches For Improving Project Success.” *The Journal of Government Financial Management*, 53(2), 12-19.

Thompson, H., Ramos-Hernandez, D., Fu, J., Jiang, L., Choi, I., Cartledge, K., and Brown, A. (2007). “A Flexible Environment For Rapid Prototyping And Analysis Of Distributed Real-Time Safety-Critical Systems.” *Control Engineering Practice*, 15(1), 77-94.

Torchiano, M., Jaccheri, L., Sørensen, C. F., and Wang, A. I. (2002). “COTS Products Characterization.” in *Proceedings of the 14th International Conference On Software Engineering And Knowledge Engineering*, ACM, 335-338.

Tran, K. T. (2012). “Software Reuse Success Strategy Model: An Empirical Study Of Factors Involved In The Success Of Software Reuse In Information System Development.” Dissertation, Trident University International.

Tranfield, D., Denyer, D., and Smart, P. (2003). “Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review.” *British Journal of Management*, 14, 207-222.

Tucker, P. (2017). “The Army Seeks Internet-of-Battlefield-Things, Distributed Bot Swarms.” *Defense One*, Retrieved 19 July 2017 online at: http://www.govexec.com/defense/2017/07/army-seeks-internet-battlefield-things-distributed-bot-swarms/139551/?oref=govexec_today_pm_nl.

Ulkuniemi, P. and Seppanen, V. (2004). “COTS Component Acquisition In An Emerging Market.” *IEEE Software*, 21(6), 76-82.

United States Code. Title 10, United States Code, Subtitle A, Part IV, Chapter 140, Section 2377. Preference For Acquisition Of Commercial Items. Washington, DC: US Government Printing Office.

United States Code. Title 10, United States Code, Section 2501. National Security Objectives Concerning National Technology And Industrial Base. Washington, DC: US Government Printing Office.

United States Code. (2002). Title 10, § 2533a, Requirement to buy certain articles from American sources; exceptions (“Berry Amendment”). Washington, DC: US Government Printing Office.

United States Congress. Competition in Contracting Act of 1984, Implemented as part of Deficit Reduction Act of 1984, P.L. 98-369, §§ 2701-2753, 98 Stat. 1175 (1984).

United States Congress. Federal Acquisition Streamlining Act (FASA). Title VIII, Subtitle A, SEC. 8104, Sec. 2377, (b)(1-4).

United States Congress. 1996. Public Law 104-106, The Clinger Cohen Act.

United States Congress. Section 4201 of the National Defense Authorization Act for Fiscal Year 1996 (Public Law 104-106, Section 357, February 10, 1996).

United States Congress. National Defense Authorization Act of 2001,Section 811 of Public Law 106-398.

United States Congress. Services Acquisition Reform Act of 2003.

United States Congress. Federal Information Technology (IT) Acquisition Reform Act (FITARA) of 2014.

United States Congress. National Defense Authorization Act of 2013, Section 831

United States Congress. National Defense Authorization Act of 2015.

United States Congress. National Defense Authorization Act of 2016.

United States Congress. National Defense Authorization Act of 2017.

United States Congress. National Defense Authorization Act of 2017, Section 805, MOSA Public Law 114-328.

United States Congress. National Defense Authorization Act of 2017, Section 879 (Public Law 114-328).

U.S. Court of Federal Claims (USCOFC). (2016). “PALANTIR USG, INC., Protestor, v. UNITED STATES, Defendant.” Filed 3 Nov 16. No. 16-784C. 129 Fed. Cl. 218; 2016 U.S. Claims LEXIS 1716.

US Debt Clock.org. (2017). Attained online 30 July 2017 at: http://www.usdebtclock.org/.

U.S. Office of Management and Budget. (2016). “Circular No. A–11: Preparation, Submission, And Execution Of The Budget.” July 2016. Washington, DC: Author.

U.S. Office of Management and Budget. (2016). “Circular A-130: Managing Federal Information as a Strategic Resource.” July 28, 2016. Washington, DC: Author.

U.S. Office of Personnel Management. (2015). “M-15-14: Management and Oversight of Federal Information Technology.” 10 June 2015. Washington, DC: Author.

U.S. Office of Personnel Management. (2016). *FITARA Common Baseline Implementation Plan, version 2.* Fiscal Year 2016. Washington, DC: Author.

Webster, J. and Watson, R.T. (2002). “Analyzing the Past to Prepare for the Future: Writing A Literature Review.” *MIS Quarterly*, 26(2), 13-23.

Weindelmayer, F., Coyle, F., and Haynes, P. (2008). “An Evaluation Of A Real-Time SOA Implementation For The U.S. Surface Navy,” NAVSEA. Attained online 3 July 17 at: http://www.omg.org/news/meetings/workshops/Real-time_WS_Final_Presentations_2008/Session%207/07-04_Weindelmayer_et_al.pdf

Witek, R. J. (2015). “Exploring 21st Century Acquisition Strategies Of The Joint Strike Fighter Program.” Dissertation. Northcentral University.

Wolfe, F. M. (1986). *Meta Analysis: Quantitative Methods For Research Synthesis*. Beverly Hills, CA: Sage.

Yang, Y., Bhuta, J., Boehm, B., and Port, D. N. (2005). “Value-Based Processes For COTS-Based Applications.” *IEEE Software*, 22(4), 54-62.

Yin, R.K. (2009), *Case Study Research: Design and Methods*, Sage Publications: Los Angeles, CA.

Younossi, O., Arena, M.V., Leonard, R.S., Roll, Jr., C.R., Jain, A., and Sollinger, J.M. (2007). “Is Weapon System Cost Growth Increasing?: A Quantitative Assessment of Completed and Ongoing Programs.” RAND Corporation: Santa Monica, CA.

Zahra, S.A. and George, G. (2002). “Absorptive Capacity: A Review, Reconceptualization, And Extension.” *Academy of Management Review*, 27(2), 185–203.

Appendix A. Relevant Literature

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
1	Grant	2000	N	DoD, For-profit firms, University	34 Case Studies (24 modified COTS)	E	Explaining	Knowledge Creation	None	No successful examples of modified COTS found. Modifications are "minor" if they "do not slip a product off the evolutionary track it otherwise would have followed in the marketplace." Research does not address security issues, and ignores intellectual property rights. Extensive list of findings, lessons learned, and best practices.
2	Gansler and Lucyshyn	2008	N	DoD	5 Case Studies	E	Explaining	Knowledge Creation	None	COTS implementations result in: shorter development time, improved performance, lower acquisition costs, greater availability of logistics support, and increased competition – particularly from small businesses. The requisite policies to effect COTS implementations are in place. More leadership is required. Report lacks specific, explicit recommendations.
3	Scacchi and Alspaugh	2016	N	DOD Software-intensive command, control, communication, cyber and business systems	N/A	C	Design & Action	Disseminati on	None	Benefits of open architecture (independent lines of effort) are expected to shorten development and fielding time. "Six key issues now found in the Defense software ecosystem: (1) unknown or unclear software architectural representations; (2) how to best deal with diverse, heterogeneous software IP licenses; (3) how to address cybersecurity requirements; (4) challenges arising in software integration and release pipelines; (5) how OSS evolution patterns transform software IP and cybersecurity requirements; and (6) the emergence of new business models for software distribution, cost accounting, and software distribution" (p. 163).
4	GAO/AIM D-00-270	2000	N/A	5 U.S. Gov't Agencies	Gov't auditing standards	N/A	N/A	N/A	N/A	Examines COTS implementations (PeopleSoft or Oracle) of HR functions in 5 government agencies: DOD, VA, GSA, HHS/CDC, and DOL. DOD: Cost growth by $248M; Cost increases were attributed to developmental delays, vendor revisions to the COTS products, and limited customization. Schedule slip for additional testing; DOL: savings of $3M due to the elimination of about 30 FTEs. $44.5M cost increase due to lack of maturity of the vendor's COTS application, higher billing rates, and underestimated implementation costs, including database, hardware, and end-user equipment needs. VA: 2 years late due to union negotiations, cultural change, additional development and testing, and the desire for a seamless integration of all COTS and custom-designed applications. $247M cost increase due to inflation and cost overruns stemming from unanticipated expenditures for extended development time frames, software maintenance for an added 2 years, additional shared service center equipment, more marketing and contractor services, upgrades to primary vendor software, and regulatory changes to self-service functionality.
5	GAO-13-315	2013	N/A	USAF	Gov't auditing standards	N/A	N/A	N/A	N/A	USAF has not implemented COTS products for satellite network control to the extent possible; whereas, COTS products are less expensive than custom ones and can be modified to meet user's needs.
6	GAO-08-331R	2008	N/A	USMC	Gov't auditing standards	N/A	N/A	N/A	N/A	Major schedule delays because the Marine Corps was optimistic in its belief that using commercial off-the-shelf systems with some modifications could provide a solution to meet the need for an internally transportable system.
7	GAO-05-189	2005	N/A	DOD	Gov't auditing standards	N/A	N/A	N/A	N/A	DOD has not adequately followed some important best practices associated with COTS-based system acquisitions. DOD has not adequately recognized the needs of end-user organizations for the time and resources to integrate DIMHRS (Personnel/Pay) with their respective legacy systems and to prepare their workforces for the organizational changes that the system will introduce.

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
8	Curry, Price, and Sabin	2016	N	UK Military Training via computer gaming	4 Interviews	E	Explaining	Dissemination	None	The use of computer games in preparing UK forces for operations in Iraq and Afghanistan showed they had a significant positive impact. The commercial games industry's capability exceeds that of the military. The defense community is not the driving force in IT development; rather, the market is. Games incorporated as training improved soldiers' training performance.
9	O'Halloran, Hall, & Rapanotti	2017	Y	UK naval vessels – safety-critical distributed control system	Case Study	E	Explaining	Knowledge Creation	POE	Examines the application of an integrated approach to safety engineering in which the engineering process is driven by assurance. Based on the emerging Problem Oriented Engineering (POE) framework for problem solving. COTS usage in safety critical systems has grown since the mid-1990s in order to reduce costs and development time. Assurance driven design (ADD) approach was able to: (1) "engage various stakeholders and capture their participation throughout the analysis, specification and design stages related to the V-model; (2) capture the stakeholder requirements and provide rich traceability of the solution in the form of transformation diagrams and structured prose; and (3) lead, through stakeholder participation, to a validated solution with an agreed safety justification" (p. 64).
10	Hall & Rapanotti	2016	Y	Software Engineering	Theory Building	C	Explaining	Knowledge Creation	Multiple	Proposes a design theory for software engineering. Cites Gregor (2006) as a need for IS theory. Relies on The Reference Model of Gunter et al. (2000). Relies on their own *Reference Model for Requirements*. Developed from work on Problem Oriented Engineering – "a practical engineering framework with an accumulated body of work spanning over a decade, which includes practical application and evaluation through a number of real-world engineering case studies" (p. 1).
11	Incze	2011	Y	Navy AUV search and survey missions	Case Study	E	Analyzing	Dissemination	None	"Lightweight Autonomous Underwater Vehicles (AUVs) were developed for Naval Special Warfare (NSW) Group 4 search and survey missions from a commercial AUV baseline through integration of commercial off-the shelf (COTS) hardware components, and through software development for enhanced on-board Command and Control functions" (p. 1955). "Economical, man-portable AUVs can be used effectively to meet mission requirements for REA [rapid environmental assessment] by forward deployed tactical units" (p. 1955).
12	Horowitz & Lambert	2006	N	COTS Software integration	N/A	C	Design & Action	Innovation	None	"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). Presents a framework (called "learn as you go") for planning and adjusting milestone sequences in assembling off-the-shelf software components." "Addresses the need for principles and methodology to assess and harmonize technical, operational, and programmatic risks in the assembly of information systems from off-the-shelf components" (p. 287). "The technology directed at software integration for Internet-based distributed systems was labelled as enterprise application integration (EAI) technology" (p. 286). Compares the process steps of a development project to an assembly project. For an assembly project, it typically takes between six and nine months to establish an initial operational prototype.
13	Carney and Oberndorf	n.d.	N	Government	N/A	C	Design & Action	Dissemination	None	COTS Commandments – 10 axioms.
14	Bovio, Cecchi, and Baralli	2006	Y	Military application of AUV – NATO; MIT	Experiment	E	Analyzing	Knowledge Creation	None	Reviewed research surrounding applications of autonomous underwater vehicles (e.g., mine countermeasures and rapid environmental assessment). "Current AUV technology is sufficiently mature to complement existing MCM assets (mine hunters and EOD divers) and improve their performance. Of particular interest is the capability to ship overnight small AUVs anywhere a crisis might occur and to place the appropriate sensors (sonar, optical, magnetic) in close proximity of mines without risking human lives" (p. 123).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
15	Thompson, Ramos-Hernandez, Fu, Jiang, Choi, Cartledge, Fortune, and Brown	2007	N	COTS Hardware; Rolls-Royce supported University Technology Centre; Distributed control systems	N/A	C	Design & Action	Dissemination	None	“Great opportunities thus exist to produce high-performance, dependable distributed systems. However, the key element that is missing is software tool support for systems integration” (p. 77). Manufacturers have a preference for supplying proprietary tools that program their products. Hardware will likely become obsolete within 2–3 years; however, large systems such as aircraft, ships, and cars can have a 10-30 year lifecycle, creating an obsolescence problem. For software system modelling, there is not a single tool that covers many disciplines. “Co-simulation is one of the best ways to develop complex systems as it allows parts of the system to be integrated and tested through virtual prototyping” (p. 79). “A flexible multi-disciplinary co-simulation environment has been described that has been developed for analysis and integration of distributed control systems” (p. 93)
16	Jilani	2008	N	Component-Based Software Development (CBSD)	N/A	C	Analyzing	Dissemination	None	Explains component-based software engineering (CBSE) and its associated issues. Software vendors are selling COTS components; thus, “requirements engineering techniques have to change to deal with more flexible requirements to provide a match between stakeholder requirements and COTS component’s services” (p. 203). A software component is defined as “a software element that conforms to a component model and can be independently deployed and composed without modification according to a composition standard” (p. 203). “Not only must engineering activities such as requirements specification change, but so must the acquisition processes and contracting strategies” (p. 203). Contrasts a CBSD life cycle (steps = find, select, create, adapt, deploy replace) to a traditional one (steps = requirements, design, implement, test, release). COTS products have their problems: incompatibility, inflexibility, complexity, versioning. New software metrics to guide quality and risk management are emerging in a CBS by identifying and quantifying various factors contributing to the overall quality 5 cost drivers of integration: product and vendor maturity (including support services); customization and installation facilities; usability; portability; and previous product experience.
17	Gump, Mazzuchi, and Sarkani	2015	N	NSA secure mobile	Systems Engineering with Case Study Validation	E	Design & Action	Dissemination	None	“Commercial Solutions for Classified (CSfC), the NSA term for commercial off-the-shelf (COTS) secure communications, coupled with published capability packages allows a developer to field a secure communications solution rapidly built entirely on COTS technology” (p. 71). Proposes a secure mobile communications architecture that purports to address: (1) the rapidly evolving commercial mobile security market and (2) leveraging commercial technologies to field the latest technologies in the least amount of time and at the lowest cost. “NSA has developed a range of “capability packages” (CPs) (Campus Wi-Fi, Mobile Access, etc.) that provide guidance for the development of these capabilities” (p. 71). “NSA has deemed COTS-based secure communications leverage commercial technology secure for classified communications” (p. 72). NSA mandates Advanced Encryption Standard (AES) commercial encryption with the extra security realized by Elliptic Curve Certificates (ECC). 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. Grey market products should be avoided because of the supply chain risk of being compromised. Provides a COTS integration process for CSfC.

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
18	Cameron, Stumptner, Nandagopal, Mayer, & Mansell	2015	Y	Real time software system (RTS) development – military application, C^2	Math modeling; Simulation	E	Predicting	Knowledge Creation	None	"Present a novel approach to RTS development where the orchestration of real-time processes is decentralised among the services within a fully distributed rule-driven process framework" (p. 202). The "framework wraps around COTS components implementing individual processing steps in a decentralised real-time process" (p. 202). "The significance of Service-Oriented Architecture (SOA) is that it represents a style where cohesion replaces coupling. That is, where similar components, rather than being coupled together, are organised into layers" (p. 202). Of the following new standards – Life-Cycle Management System (IDLMS), Enterprise Decision Management (EDM), Service Component Architecture (SCA), Event Stream Processing (ESP), Complex Event Processing (CEP), Enterprise Service Bus (ESB) and, not least, Business Process Management (BPM) , CEP provides the most important method of decoupling. "Applying a layered approach to RTS software comes at a cost in terms of performance" (p. 203). "In a typical mission critical system, this tolerated rate of failure is one failure in 10^5" (p. 203). Networked Service-Oriented Architecture "is seen as the next step in the evolution of mission critical Command and Control (C2) systems" (p. 203). There is a "mismatch in technology between what needs to be achieved with RTS and what is offered by SOA" (p. 203). "There is a need for hybrid architectures, where there is a natural decoupling of components of the system that need to be hard real-time and time synchronised, such as in the case of sensors and effectors with those components that can be made more interoperable by operating in a more discrete and asynchronous manner" (p. 203). "The motivation for such hybrid architectures comes from the desire for military systems to be able to distribute and re-combine in new configurations to share data and information in order to achieve an information advantage over platform-based adversaries" (p. 203). Two empirical studies test the performance of the system. Concludes that firm-real-time Service Oriented Architectures are feasible.
19	Weindelmayer, Coyle, & Haynes	2008	N	Navy Real-time SOA	Experiment	E	Predicting	Knowledge Creation	None	"Real-time Java technologies can be successfully integrated with Web Services technologies to increase the determinism and performance of a real-time SOA application" (p. 45).
20	Naegle & Petross	2010	N	Navy P8 Maritime Patrol and Reconnaissance aircraft software support	N/A	C	Design & Action	Dissemination	None	"Analyzes potential system software maintenance drivers, and presents advantages and disadvantages for three differing software support management options" (p. i.). Recommends a hybrid structure of government and contractor support.
21	Boudreau	2006	N	Submarine Acoustic Rapid COTS Insertion	Case Study	E	Explaining	Knowledge Creation	None	"The results of A-RCI were astounding cost reduction, dramatic improvement in technical performance, successful use of COTS hardware in a critical warfighting application, logistics support improvements, and an acquisition model that might have broad applicability across the DoD" (p. 3). Regained acoustic superiority. "The lifecycle cost of A-RCI/APB has improved by nearly 5:1 over its predecessor system" (p. xvi.). "Software and hardware improvements could be implemented in a significantly reduced cycle time" (p. xvi.). The A-RCI/APB example shows that modular open system architecture can be applied successfully to a legacy system.

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
22	Ford & Dillard	2009	Y	Acoustic Rapid COTS Insertion	System dynamics methodology; Simulation	E	Explaining & Predicting	Knowledge Creation	Control theory	Models the Open Architecture and Evolutionary Acquisition process (called RCIP – rapid capability insertion process) based on the successful acoustic rapid COTS insertion program. ARCI performance: mean operator detection success rate improved 4-fold from 23% to 87%. Mean number of false alarms per run decreased 40% from 1.0 to .58. Mean initial detection and classification time improved by 27 minutes. Mean contact holding time improved by 25 minutes. Phase I improvements were installed 18 months after MDA. Reduced "budget allocations across SCN, OPN, O&MN, RDT&E, and MilCon by over 50% ($7.6 billion to $3.6 billion) when the 1983-1993 budget allocations are compared to the 1996-2006 allocations – a 6-fold reduction in development and production costs" (p. 217). Attained over $25 million in cost avoidance for logistics support. RCIP model is a generic model of program management that partially explains ARCI success. "Successfully implementing a sustainable RCIP program will require a method to address potential burnout of the government program-management workforce" (p. 230). The model demonstrated RCIP's potential to improve program performance; however, when identified risks were inserted into the model, performance decreased (e.g., including increased oversight, the use of more new development, and the resulting integration scope and risk).
23	Rendon	2007	N	DOD contracting - modular open systems architecture (MOSA)	N/A	E	Analyzing	Disseminati on	None	Analyzes "the effectiveness of the implementation of MOSA in Navy acquisition programs by investigating the results of MOSA-internal assessments, specifically the results of the Open Architecture Assessment Tool (OAAT)" (p. 264). OAAT assesses openness along two dimensions: business and technical. "The business/programmatic dimension criteria include questions that address: Open Architecture, Modular Open Design, Interface Design and Management, Treatment of Proprietary Elements, Open Business Practices, Peer Review Rights, and Technology Insertion. The technical dimension criteria cover essential OA design tenets of Interoperability, Composability, Reusability, Maintainability and Extensibility" (p. 264). "This research indicated that the greater degree of jointness in acquisition roles and responsibilities, as well as the greater degree of contractor-developed acquisition documents, will lead to a higher level of openness" (p. 263).
24	GAO-06-995	2006	N/A	USAF commercial contracting	Gov't auditing standards	N/A	N/A	N/A	N/A	"The benefits to the government of commercial acquisition have not been demonstrated. Little evidence has been collected on the claimed benefits such as cost savings, better pricing, increased access to commercial vendors, and greater numbers of commercial firms to compete for Air Force contracts" (p. 19).
25	DODIG D-2006-115	2006	N/A	DOD commercial contracting	Gov't auditing standards	N/A	N/A	N/A	N/A	"Contracting officials did not adequately justify the commercial nature of 35 of 42 (83 percent) commercial contracts for defense systems and subsystems awarded in FYs 2003 and 2004. As a result, contracting officials inappropriately awarded contracting actions that did not achieve the benefits of buying truly commercial products and relinquished price and other oversight protections under the Truth in Negotiations Act that would have allowed better visibility to establish fair and reasonable prices" (p. i.).
26	Julian, Lucy, & Farr	2011	N	COTS Component Selection in military systems	Interviews	E	Design & Action	Innovation	None	Proposes the value hierarchy model as a useful set of COTS component selection criteria. The model "uses a qualitative, weighted structure of criteria that are scored using a quantitative value to assess a component's performance against that set of criteria" (p. 65). Assesses criteria for the manufacturer, the product, and the technology in seven categories: manufacturer capability (product control, financial strength, quality management system, staffing, equipment, organizational, and facilities), manufacturer experience (historical experience and performance), quality (reliability and maturity), technical specifications (part's ability to meet application specs, ability to meet manufacturer specs, and ability to meet packaging specs), logistics and support (availability, customer support, and flexibility), total costs of ownership (hardware related costs, software related costs, and technology refresh and insertion costs), and technology evaluation (maturity and standards). Provides specific metrics for each criterion.

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
27	Thomas & Jajodia	2004	N	ERP implementations in the public sector	N/A	C	Design & Action	Disseminati on	None	90 percent of ERP projects are late or over budget. Offers Best practices for public sector ERP implementations.
28	Guntersdo rfer & Kay	2002	N	Software component patenting	N/A	C	Design & Action	Disseminati on	None	A U.S. patent gives the inventor protection for up to 20 years from the filing date against using, making, or selling an invention. Software has generally been patentable since a U.S. Supreme Court ruling in1981. "Patenting successful methods might work in two distinct, positive ways. First, competitors might settle for licensing the patented technology, concentrating on its application rather than its reinvention in a minimally different form. This would lead to fewer competing standards (addressing the technical issue). Second, competitors might decide to focus on developing truly innovative solutions patentable in their own right, rather than merely incremental tweaks. Both approaches could lead to better scientific progress than the current approach of imitating existing technology" (p. 81). "Component development is not obviously profitable for two reasons. First, a component's development costs increase or its target market decreases with every additional, newly established interaction technology. Second, factors in the software development process make reuse unattractive. Project management often chooses cheap reimplementation of existing functionality over buying expensive licenses. Patents, however, prohibit unlicensed reimplementation while supporting licensed code reuse" (p. 81). "Patent protection buys inventive programmers lead time that lets them produce higher-quality products using better but more time-consuming software engineering methods" (p. 81).
29	Keil & Tiwana	2005	N	COTS enterprise software	Survey 126 organizations, 25.2% RR; Regression & Conjoint Analysis	E	Explaining & Predicting	Knowledge Creation	None	Provides ERP buyers an assessment framework for evaluating COTS software, and provides ERP suppliers the factors that buyers value most. More than half of all enterprise systems implementations fail. The seven characteristics that IT managers repeatedly mention as being important were: functionality, reliability, cost, ease of use, vendor reputation, ease of customization, and ease of implementation. Functionality and reliability impacted perceived value the greatest (above the other significant predictors: cost, ease of customization and ease of use).
30	Mariani & Pezze	2007	N	COTS integration compatibility	N/A	C	Design & Action	Innovation	None	"Extensive component reuse creates new integration problems that traditional test and analysis techniques can't adequately address" (p. 84). Proposes a technique called *behavior capture and test* (BCT) that detects COTS component incompatibilities by dynamically analyzing component behavior. "Automatically deriving and checking models presents several issues: • Component interactions involve not only simple data but also complex objects that must be suitably monitored. • We must reduce the enormous number of I/O and interaction traces to models that generalize the observed behavior. • The system must automatically identify behaviors incompatible with the models previously inferred" (p. 78). The BCT method enables: identifying incompatibilities and faults as soon as they occur, identifying faulty program states prior to observing a failure, and improved system debugging.
31	Ulkuniemi & Seppänen	2004	N	COTS component acquisition in emerging market	Interviews	E	Analyzing	Knowledge Creation	None	Presents a typology of the emerging COTS component market. "The main challenges included • Scanning, evaluating, and selecting COTS components • Analyzing component cost and value • Defining component warranties and liability • Integrating components into the in-house software architecture • Managing the overall component acquisition process" (p. 77). Proposes 4 types of markets depending on whether **demand** and **supply**, respectively, are homogeneous or heterogeneous: • Het-Het: "Suppliers offer components and services closely packaged into one offering. Competing offerings are difficult to compare. Customers have their own unique needs. Tailoring the software is often required" (p. 78). • Hom-Het: "Suppliers offer components and services as an integrated

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
										offering. Competitive offerings are difficult to compare. Customers can use a variety of different kinds of components, due to CBSE" (p. 78). • Het-Hom: "Suppliers offer components based on standards • and provide services for an additional (high) cost. Customers have not adopted standards in their software engineering and find it difficult to use COTS software" (p. 78). • Hom-Hom: "Suppliers offer components based on standards and provide services for an additional (high) cost. Customers have adopted the standards in their software engineering" (p. 78). The different market types each requires a different acquisition process: • Het-Het: "cooperation project. Keep organization's component needs flexible, actively monitor suppliers' offerings, and incorporate knowledge as early as possible in the software architecture development. Use known, evaluated suppliers. Monitor other buyers and initiate cooperative efforts with competitors and suppliers to homogenize industry demand. Define the actual object of exchange in cooperation with the supplier, complete solution type. Expect exchange mechanism to be close and cooperative, with informal commitments or not very detailed formal contracts. Emphasize supplier relationship management, cooperation, mutual trust, and commitment. Monitor development of the industry supply" (p. 81). • Hom-Het: "horizontal competition. Recognize that industry standards might not address organizational needs, and adapt to market conditions by defining needs more flexibly. Suppliers might offer standards-based components but prefer to sell complete, tailored packages. For possible cost savings, negotiate with supplier to abstract pieces of the offering. Consider developing long-term cooperative relationship with supplier to minimize horizontal competition. Develop ways to influence the supplier's future component roadmap. Participate in industry standardization efforts and leverage demand homogeneity to increase supply homogeneity" (p. 81). • Het-Hom: competitive supply management. Adopt CBSE but, as needed, adapt own software system architecture and interfaces to the supply. Monitor and participate in market standardization efforts; homogeneity of demand might be increasing. Where suppliers offer abstracted components and services, prepare requirements and criteria accordingly. Emphasize value and cost analysis. Adapt to transactional exchange style, which suppliers are more likely to pursue in this market type. If the homogeneous supply meets organizational needs, consider using competitive strategy toward suppliers. Carefully manage contractual clauses in the supplier interface management. Monitor and adapt to supply development" (p. 81). • Hom-Hom: "ideal market. Define organizational market needs around CBSE use and standards-based software architectures. Define clear processes to identify and acquire components needed. Participate in and adapt to industry standardization efforts. If supplier abstracts component and services, develop value and cost analysis methods for both elements. Using component brokers will likely lead to highly transactional and distant relationships. Carefully plan and coordinate interactions with supplier, managing direct relationships in a more transaction-based manner and defining terms, guarantees, and responsibility in contracts" (p. 81).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
32	Yang, Bhuta, Boehm, & Port	2005	N	COTS-base application development – University and industrial projects	N/A	C	Design & Action	Innovation	None	Principles for COTS-based application (CBA) development: “1. Process happens where the effort happens. In industrial projects, most effort is in gluing code and tailoring code (vs. evaluating and selecting COTS products). In small, e-service systems, however, most effort is in evaluating and selecting COTS products. 2. Don’t start with “requirements.” 3. Avoid premature commitments, but have and use a plan. 4. Buy information early to reduce risk and rework. Hence, evaluate the COTS project based on risk exposure involved in selecting the wrong combination rather than on COTS products’ costs. 5. Prepare for COTS change” (p. 55). Suppliers upgrade their COTS products approximately every 10 months. After an average of three releases, releases are no longer supported. “As COTS vendors try for competitive differentiation, they are likely to introduce new features that are incompatible with those of other COTS products” (p. 57). Useful COTS change-coping strategies include: • “investing effort in a proactive COTS market-watch activity; • developing win-win rather than adversarial relations with COTS vendors; • reducing the number of COTS products and vendors; • reducing inter-COTS coupling via wrappers, mediators, or interoperability standards; • contracting for delivery of latest-release COTS products; and • developing and evolving a lifecycle COTS refresh strategy that’s synchronized with business cycles (such as annual product models or 18-month operator retraining cycles), using tailored versions of the process framework discussed next” (p. 57). Present a value-based, 12-step process CBA process decision framework that resulted in 93.7 percent on-schedule delivery of highest-value capabilities across 20 projects.
33	Reifer, Basili, Boehm, & Clark	2003	N	COTS-based systems maintenance	N/A	C	Design & Action	Dissemination	None	“During maintenance, COTS products undergo a technology refresh and renewal cycle. As part of this activity, maintainers decide whether to upgrade their COTS products or retain old versions. If they choose to retain old versions, they’ll eventually reach the point where the vendor no longer supports those versions. If they choose to update, they must synchronize the associated update with their release cycle and with product updates other vendors are making. They must also coordinate the update of wrappers and glue code so that they will work with the new versions” (p. 94).8 Lessons learned: “1. The refresh and renewal process for CBSs must be defined a priori and managed so COTS package updates can be synchronized with each other and the organization’s release and business cycle. 2. COTS software capability and quality evaluation must be managed as a continuing task during the maintenance phase. 3. The cost to maintain COTS-based systems equals or exceeds that of developing custom software. 4. The most significant variables that influence the lifecycle cost of COTS based systems include the following (in order of impact): number of COTS packages that must be synchronized within a release, technology refresh and renewal cycle times, maintenance workload (the amount of effort software engineers expend to handle the task at hand) for glue code and wrapper updates, maintenance workload to reconfigure packages, market watch and product evaluation workload during maintenance, maintenance workload to update databases, maintenance workload to migrate to new standards, COTS maintenance license costs. 5. Maintenance complexity (and costs) will increase exponentially as the number of independent COTS packages integrated into a system increases. 6. Software engineers must spend significant time and effort up front to analyze the impact of version updates (even when the decision is made not to incorporate the updates). 7. Flexible CBS software licensing practices lead to improved performance, reliability, and expandability. 8. Wrappers can be effectively used to protect a CBS from unintended negative impacts of version upgrades” (p. 95-96).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
34	Mehlawat & Gupta	2015	Y	COTS Selection, modular software systems	Optimization modelling	E	Explaining & Predicting	Innovation	Fuzzy set theory; credibility theory	Develops and demonstrates a multi-objective, credible model for a COTS products selection problem under a fuzzy environment. "The objective functions of the proposed model are to minimize the total cost, size, and execution time of a modular software system subject to many realistic constraints including system reliability, delivery time, and incompatibility among the COTS products" (p. 354).
35	Lobur	2011	N	COTS-based disability caseload management system implementation in State government	Case Study	C	Analyzing	Dissemination	None	"One of the great challenges of customizable COTS implementations is determining which of the product's basic features are a best practice that should be adopted and which must be modified to suit existing processes" (p. 11). The greatest success factor was the role of "user coordinator" who wrote specifications for vendor customizations, developed training materials, and provided training of the new system.
36	Software Engineering Institute	2016	N	RFP Practices – Government Contracting	N/A	C	Design & Action	Dissemination	N/A	Written by the National Defense Industrial Association's System Engineering Agile Working Group under contract FA8721-05-C-0003 Addresses DOD's need for agile software development (iterative systems developments)-reduced cycle times, flexibility to adapt to changing conditions and user needs. Written to support the authors of RFPs in incorporating agile concepts into programs. Notes a common misunderstanding that the development methodology must mirror the acquisition lifecycle. Compares traditional waterfall development to an agile method. "Two Agile principles-Business personnel, customers or their advocates, and implementers must work together daily and continuous attention to technical excellence and good design enhances agility" (p. 12). Provides sample Section M evaluation criteria – 3 technical sub-factors: agile development process, systems engineering practices, and system test and delivery.
37	Couts & Gerdes	2010	N	Healthcare ERP	N//A	C	Design & Action	Dissemination	None	The project life cycle when implementing a COTS product differs from that of a custom development project. Minimize custom coding. Adapt requirements to the market's capabilities as much as possible. The project team must document selection criteria for the COTS package and for the system integrator (functionality, interoperability, transparency performance, security, safety, maintainability, update cycle, maturity, upward compatibility of revisions, quality, reliability, architecture, lifecycle costs, and vendor). Market analysis and screening are necessary. Review session (a.k.a., or conference room pilots) let users provide requirements and design feedback on the basis of early user interface versions. Consider a systems integrator. The buyer may need additional hardware and training. Know the product's underlying coding language and technology in the event that the vendor goes out of business and the buyer must therefore maintain the code. Consider a software escrow agreement (vendor depositing source code with independent 3rd party). Periodically assess the product line's stability. One way is to determine how much the product contributes to the vendor's bottom line. Also examine the growth of the product line's market and the vendor's market share. Consider a test installation.
38	Morisio, Seaman, Basili, Parra, Kraft, & Condon	2002	Y	NASA software development	Observation – 25 structured interviews; constant comparison	E	Explaining	Knowledge Creation	None	Examines 15 COTS-based software development projects within NASA. Differences from traditional development processes included requirements definition, COTS selection, high level design, integration, and testing. Proposes new processes and guidelines for these differences. "New activities identified in COTS-based processes are: product evaluations, product familiarization, and vendor interaction (of technical, administrative and commercial kinds)" (p. 198). "Architectural issues, especially the difficulties of integrating components, must be considered" (p. 198). COTS-based development is most challenging in requirements, design, and project management.
39	Clark, Clarke, Panfilis, Granatella,	2004	N	Europe -Selecting COTS software components	Case Study	E	Design & Action	Innovation	None	Discusses the search techniques in a component broker project funded by 8 European partners called *CLear And Reliable Information For Integration* (CLARiFi) that supports integrators in the selection of components for systems from large component markets/repositories such as Component Source. "CBSE is a ''best-fit'' problem, where the integrator finds an acceptable compromise

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
	Predonzani, Sillitti, Succi, & Vernazza									between the requirements, the system architecture and the design of the available components" (p. 324). Adjustments of search queries may be necessary because: • "The number of candidates can be wrong: either unmanageable or too narrow. • The components may be not adequate due to some discrepancies between their description and what they actually do. • The components may not fit together due to incompatibility. • The system design may not be the right view to decompose the problem in parts and to look up components that fit the parts" (p. 324). The developed search technique by CLARiFi was superior to ComponentSource on the following criteria: multiple points of view, system point of view, component point of view, effort required to classification, Information for integrators, comparison of attributes, ranking of components compared to an ideal component, alternative selection and rollback, search and selection refinement, storing of a context, and certification of components. Lessons learned: "the classification must have a semantic richness to improve the comprehension among suppliers, the broker, and integrators" (p. 329). Property values that suppliers provide are often qualitative. There are no scale or proximity measures to compare them. Integrators attach more importance to certified components and properties.
40	Cechich & Piattini (2007)	2007	Y	COTS Selection	Case Study	E	Design & Action	Innovation	None	Proposes an early functional suitability measurement procedure for determining the suitability of COTS candidates. Aims at reducing the number of candidates by selecting some very quickly based on a brief review of key functional issues. Few candidates are fully evaluated allegedly making process more cost-effective. Lessons learned: "(1) Early measurement of functional suitability can reduce the number of candidates allowing a more objective value for decision making. (2) Early detection of functionality requires that standards on how COTS components are documented be reinforced. (3) Requirements expressed as scenarios might facilitate searching and filtering, but a common understanding about the required level of detail (abstractness) must be specified. (4) Composer's skills actually lead the search. (5) Assessing vendor's reliability is as much important as the identification of functional candidates itself. (6) Classification is not straightforward" (p. 118).
41	Gregor	2006	Y	IS Theory	Literature Review	C	Analyzing	Knowledge Creation	Multiple	Examines the structural nature of theory in the discipline of Information Systems (IS). "A characteristic that distinguishes IS from other fields is that it concerns the use of artifacts in human-machine systems" (p. 613). "Thus, the body of knowledge that is needed draws on natural science, social science and what has been termed design science" (p. 613). "Four central goals of theory: analysis, explanation, prediction and prescription" (p. 614). Proposes five types of IS theory: (1) theory for analyzing ("says what is. The theory does not extend beyond analysis and description. No causal relationships among phenomena are specified and no predictions are made." Includes classifications and taxonomies.) (2) theory for explaining ("says what is, how, why, when, and where. The theory provides explanations but does not aim to predict with any precision. There are no testable propositions." Many case studies fall into this category. Testable propositions; conceptual models; theory is the end product.) (3) theory for predicting ("says what is and what will be [but not why]. The theory provides predictions and has testable propositions but does not have well-developed justificatory causal explanations." These types are uncommon in IS [e.g., Moore's Law]) (4) theory for explaining and predicting ("says what is, how, why, when, where, and what will be. Provides predictions and has both testable propositions and causal explanations.") (5) theory for design and action ("says how to do something. The theory gives explicit prescriptions (e.g., methods, techniques, principles of form and function) for constructing an artifact)" (p. 620).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
42	Rosa, Packard, Krupanand, Bilbro, & Hodal	2013	Y	Government ERP implementation cost estimating	Regression – 20 ERP implementations (SAP, Oracle, and Momentum)	E	Predicting	Knowledge Creation	None	"A recent survey of 187 companies that had implemented ERP systems found that 61% of the implementations exceeded schedule and 74% exceeded cost." "All major DoD ERP programs have exceeded cost and schedule estimates by more than 30%" (p. 538). Develops ERP cost and schedule models based on data collected from 20 ERPs implemented by the federal government. "The first set of models uses product size to predict ERP software engineering effort as well as total integration effort. Product size is measured in terms of the number of report, interface, conversion, and extension (RICE) objects configured and customized within the commercial ERP tool. Total integration effort captures software engineering plus systems engineering, program management, change management, development test and evaluation, and training development. The second set of models predicts the duration of ERP implementation stages in terms of RICE objects, staffing, and the number of test cases" (p. 538). The schedule growth for the five programs for which data was available ranged from 110% to 240%. Average cost growth for all 20 programs was 150%. The vendor's implementation team costs accounted for 38% of the total implementation cost.
43	Badampudi, Wohlin, & Petersen	2016	Y	Software components	Literature Review – *n*=24 studies	E	Analyzing	Knowledge Creation	None	"The component origins compared were mainly focused on in-house vs. COTS and COTS vs. OSS. We identified 11 factors affecting or influencing the decision to select a component origin. When component origins were compared, there was little evidence on the relative (either positive or negative) effect of a component origin on the factor. Most of the solutions were proposed for in-house vs. COTS selection and time, cost and reliability were the most considered factors in the solutions. Optimization models were the most commonly proposed technique used in the solutions. Conclusion: The topic of choosing component origins is a green field for research, and in great need of empirical comparisons between the component origins, as well of how to decide between different combinations of them" (p. 105). Considers 4 types of component origins: (1) In-house developed components (2) COTS (3) Open Source Software (4) Outsourced components 11 Factors: time, cost, effort, quality, market trend, source code availability, technical support, license, integration, requirements, maintenance.
44	Hauge, Ayala, & Conradi	2010	Y	OSS	Literature Review	E	Analyzing	Knowledge Creation	None	Literature review of 112 articles (59 empirical) seeking to identify how organizations adopt open source software (OSS) – provides a classification of six different ways. • Deploying OSS products • Using OSS CASE tools • Integrating OSS components • Participating in OSS communities • Providing OSS products • Using OSS development practices "Existing research on OSS adoption does not sufficiently describe the context of the organizations studied, and it fails to benefit fully from related research fields" (p. 1133). Need more empirical research on OSS. Collaborative development model. "OSS and its general lack of license fees contribute to shifting the software industry's traditional license-based business models towards service-based models. Hence, OSS is significantly influencing the ways organizations develop, acquire, use, and commercialize software" (p. 1133). Although there are minor differences between open source, free software, and free (libre) open source software (FOSS/FLOSS), this research treats them as the same. Summarizes two prior literature reviews on OSS. Limits focus to public and private software-intensive organizations. "Organizations that extend and possibly modify an OSS product increase their dependence on the product and face additional challenges related to maintenance" (p. 1136). Findings from integrating OSS (based on only six empirical papers): • "Software organizations can increase productivity and quality through integrating systematic reuse of OSS components. OSS reuse does not require

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
										any special skills and experience other than software reuse in general • Major cost with OSS is learning and understanding new components. Local knowledge and compliance to requirements were the most decisive factors in choosing components. A high number of components needed fixes or modifications • There is a need for human computer interaction experts in the OSS context. Reuse of OSS enables them to spend more time on user interface. It is challenging to decide what to contribute because of licenses and patents, and as user interface code can be considered a competitive advantage • There are many similarities in using OSS and COTS. Source code is seldom used. Hard to assess providers' (community) reputation • Identifies challenges related to modifying OSS components, and strategies (contributing, snapshot, forking, and initiating a new OSS project) for dealing with these modifications" (p. 1142). "Four strategies for dealing with these modifications: contributing to the OSS community, relying on a snapshot of the code base, forking the OSS product, or releasing modifications to the OSS product as a new OSS product" (p. 1143). "The adoption of OSS seems to be more depending on the organization adopting it and the situation in which it is adopted, than on the technology being released as OSS" (p. 1146). By treating OSS as something totally unique from other information technologies (e.g., software reuse and COTS), researchers fail to draw valuable support from related literature.
45	Maras, Lednicki, & Crnkovic	2012	Y	CBSE Symposium – software components	Literature Review; Grounded Theory	E	Analyzing	Disseminati on	None	A systematic literature review of 318 CBSE symposium papers. CBSE is not new. "At the software engineering (SE) conference in 1968, Douglas McIlroy introduced the concept of software components during his keynote speech: "Mass-Produced Software Components" (p. 61). "Today, CBSE is a standard part of SE, although the interest related to components has somewhat decreased" (p. 61). Decrease in number of CBSE citations indicates lesser interest in the topic as of late. List of topics appeared in the CBSE studies: component models, component technologies, extra-functional properties, composition and predictability, software architecture, quality issues, lifecycle, domains, and methodology. Mentions some component technologies such as: JavaBeans, CCM, EJB, J2EE, OSGi, Robocop, ASP.NET, ProCom, and Fractal. "The majority of research as a result produces "A procedure or a technique" followed by "Report" (p. 68). "CBSE has come to a mature phase where many challenges stated in early years have been solved, or it was realized that they are unsolvable" (p. 70). To retain interest from researchers and practitioners, "CBSE events should strive to bring more contributions that demonstrate the practical usage of CBSE" (p. 70).
46	GAO Decision B-295356	2005	N/A	Bid Protest	N/A	N/A	N/A	Disseminati on	N/A	Protestor's challenge that HUD"s requirement for a loan software package be COTS is denied. "While a contracting agency has the discretion to determine its needs and the best method to accommodate them, those needs must be specified in a manner designed to achieve full and open competition; solicitations may include restrictive requirements only to the extent they are necessary to satisfy the agency's legitimate needs" (p. 3). Notes that note that "the Federal Acquisition Streamlining Act of 1994, Pub. L. No. 103-355, established a preference for the acquisition of commercial items." "HUD's need for a COTS software application is driven by its desire for a reliable product with a low risk of unsuccessful performance, which it presumes a COTS product is more likely to provide. AR at 7. In addition, HUD expresses a desire to reduce the need for software maintenance, and to make it easier to find programmers who are familiar with the software, which it explains has been a problem with its reliance on dated proprietary software. HUD also expresses a desire to avoid the costs associated with developing new software" (p. 6).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
47	GAO Decision B-293093; B-293093.2	2004	N/A	Bid Protest	N/A	N/A	N/A	Dissemination	N/A	Protestor's challenge that awardee's software was not a COTS product is denied. "The determination of whether a product is a commercial item is largely within the discretion of the contracting agency, and will not be disturbed by our Office unless it is shown to be unreasonable" (p. 6).
48	GAO Decision B-294059; B-294059.2	2004	N/A	Bid Protest	N/A	N/A	N/A	Dissemination	N/A	Protestor's challenge that it should not be removed from the competitive range because of a failure to meet the requirement for a commercial item is denied. "The company still had no commercially-available Oracle database by the March 26 due date for revised proposals" (p. 4). "CCI's failure to meet this requirement creates a high risk for the government. One of the purposes of government purchases of commercially-available equipment is to avoid the risks associated with buying applications that have not yet been tested by the rigors of the open market" (p. 4).
49	U.S. Court of Federal Claims	2016	N/A	Bid Protest	N/A	N/A	N/A	Dissemination	N/A	Protestor's challenge on the basis that the Army did not consider Palantir's commercial battlefield intelligence synthesis software was sustained where the Army acted arbitrarily and capriciously in not fully considering the viability of the existing commercial software in satisfying Army needs per the requirements of 10 U.S.C.S. § 2377(a).
50	Lorell, Payne, & Mehta (RAND)	2017	N	DOD Acquisition Program Performance Assessment	Case Study	E	Analyzing	Knowledge Creation	N/A	Compares six ACAT I MDAPs that experienced extreme cost growth to four programs that experienced low (and negative) cost growth seeking key root-cause attributes. "Two main categories of common characteristics and conditions, comprising five subelements, were prominent in these programs: • premature approval of Milestone (MS) B − insufficient technology maturity and higher integration complexity than anticipated − unclear, unstable, or unrealistic requirements − unrealistic cost estimates • suboptimal acquisition strategies and program structure − adoption of acquisition strategies and program structures that lacked adequate processes for managing risk through incrementalism or through provision of appropriate oversight and incentives for the prime contractor − use of a combined MS B/C milestone is based on the assumption that little or no RDT&E is required but has often been linked to an underestimation of required development work and often led to excessive concurrency between development and production phases" (p. ix.). "The low cost-growth programs exhibit few of the key characteristics of the six extreme cost-growth programs" (p. xi.). Some of the difference could be attributed to program size, and technological and integration complexity. Recommends realistic cost estimates at MS B and incremental strategies with comprehensive and proven implementation strategies.
51	Younossi, Arena, Leonard, Roll, Jain, & Sollinger (RAND)	2007	Y	DOD Acquisition Program Costs	OLS Regressions	E	Analyzing	Knowledge Creation	None	Book examines whether weapon system cost growth is increasing. Measures cost growth at five year point past MS B. "Although DCGF [development cost growth factor] declined between the 1970s and the 1980s, from almost 1.49 to 1.37, in the 1990s, DCGF rose again to about the same level as in the 1970s-1.50" (p. 38). Development costs growth for completed programs is approximately 60% - high and not improving. "The many acquisition reform initiatives have not succeeded in lowering the development cost growth of military systems" (p. 45). Development cost growth is attributed to "overoptimism of program managers, the complexity of the technology, the scale of the program, and other factors" (p. 45).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
52	Bjornson & Dingsoyr	2008	Y	KM in software engineering	Literature Review	E	Analyzing	Knowledge Creation	KM and Organizational Learning	Literature review of knowledge management (KM) in software engineering (SE). The SE "community could learn much from the knowledge management community, which bases its theories on well-established disciplines such as cognitive science, ergonomics, and management" (p. 1056). Trend in SE of increased focus on evidence-based software engineering (EBSE). SE mostly addressed the storage and retrieval of knowledge; while knowledge creation, and the transfer and application of knowledge have garnered less research attention. "KM writings seem to focus on how to create knowledge and to a lesser degree, how to transfer knowledge" (p. 1057). The concepts studied in KM: • The impact of knowledge management initiatives • Factors that enable effective knowledge management • Factors that contribute to use of knowledge artefacts Findings: • "Knowledge pull leads to more effective knowledge management than knowledge push" • "Knowledge needs to be internalized to improve processes" • "Leadership is the most important enabler for knowledge management" • "Perceived complexity, perceived advantage and perceived risk contribute to the use of knowledge management artefacts" (p. 1063).
53	Beesley & Cooper	2008	N	KM	N/A	C	Explaining	Knowledge Creation	KM	Offers an innovation-focused framework for knowledge management (KM). There is confusion and poor understanding of the use of KM among practitioners hindering KM practices. "Knowledge is increasingly viewed as an activity within and among individuals, rather than as an object" (p. 49) such as information and data. The premise is that there is a lack of accepted definitions of key terms (e.g., information and knowledge). Holds that knowledge should be considered an activity. Data and information are objects. Knowledge has been defined as information with meaning. It "can only be amassed within individual knowledge networks" (p. 52). "Knowledge is considered to be that which is embedded within individuals and occurs either as a result of experience, or is generated through thinking or reasoning; otherwise it remains as data or Information" (p. 51). "Knowledge creation refers to the deliberate and purposeful collation of observations, data, or facts to generate new or novel ways of understanding a particular phenomenon. Knowledge acquisition refers to the successful transfer of extant knowledge to others" (p. 52) "Generative learning [is] the degree to which individuals explore, extend, amend, and develop existing knowledge networks" (p. 53), and is defined as knowledge adoption. "Within the context of the broader business community, knowledge can then be said to have been adopted when the transfer of new information (research outputs) leads to the generation of new knowledge that in turn, allows individuals to identify new opportunities relating to products, services, markets, or processes" (p. 53). "Knowledge adoption requires both contextual and procedural knowledge" (p. 53). "Procedural knowledge involves the exploration of existing knowledge structures, and recognition of how those structures do or do not relate to new information. Contextual knowledge is the awareness of one's environment, the issues emerging from it, and how they are embedded within it" (p. 53). "This implies that for knowledge to be adopted, it is not sufficient to merely make it available; it is necessary to present it in ways that help the receiver first consider the information and then explore its relevance" (p. 53). "Innovation corresponds to the application of new and creative ideas and the implementation of inventions" (p. 53). "Within the context of the broader business community, knowledge is said to have been adopted when an individual identifies new opportunities relating to products, services, markets, or processes" (p. 53). The degree to which knowledge is acquired is not only dependent upon communication, cognition and social contingencies.

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
										"Values underpin the acquisition and adoption of knowledge" (p. 56). "Once the subtle differences between knowledge creation, knowledge acquisition, knowledge transfer, knowledge adoption, and innovation are commonly understood, it is possible to more capably monitor the extent of innovations within various sectors and more aptly identify factors that more or less facilitate the transfer and adoption of knowledge in those who work within them" (p. 57). "Common understanding of the activities that mediate dissemination and innovation means future research can more clearly identify which aspects of this process are or are not being handled capably by broader industry participants and /or researchers" (p. 57).
54	GlobalPlatform	2003	N	DOD CAC Development	Case Study	E	Analyzing	Dissemination	None	White paper by GlobalPlatform – a contractor involved in the development of DOD's common access card (CAC) using COTS technology. Supports 4.5 million users and 933 ID card producing locations worldwide. Program yielded cost savings, improved readiness, increased quality of life and solved the fraud and information assurance problems. Adopted industry best practices and smart card technology (based on OSA), namely that of credit cards. Addresses issues and provides lessons learned.
55	Morrow	2010	N	Integrating COTS – MRAP Program	Case Study	E	Design & Action	Dissemination	None	"The rapid pace of MRAP acquisition is widely attributed to its use of proven technologies" (p. 1). "Although many companies produce unique MRAPs, most integrate proven components into modular vehicle designs. MRAP models such as Navistar's widely-used "Maxxpro" use readily available, universally supportable parts, while 95 percent of the components used in BAE Systems' "Caiman" MRAP are compatible with the Family of Medium Tactical Vehicles. The MRAP's modular design not only protects its crew from IEDs, but also enables rapid production due to the ease of system integration" (p. 1). "Both MOTS and COTS are integrated in the M-ATV design with little additional modification. Not only is its chassis based on a common military truck used in Afghanistan and Iraq, but the M-ATV uses the TAK-4 suspension system common in tractor-trailers.9 Thus, like the MRAP, the M-ATV embodies proven military and commercial components in a new program" (p. 2). Lessons learned: "Integrating low-level COTS and MOTS subsystems appears to shorten the overall system's acquisition schedule" (p. 2). "New or highly modified components thus appear to cause difficulties for subsystems integration" (p. 2). "Receiving DoD's highest "DX" priority rating" (p. 2) helped acceleration. "Using multiple sources helps control for risk on the production line" (p. 2). "New acquisition programs may achieve rapid production schedules if they integrate existing COTS and MOTS to meet new requirements, though doing so requires creativity on the part of their subsystem integrators" (p. 2).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
56	DOD Defense Science Board	2009	N	DOD Acquisition	Case Study	E	Design & Action	Disseminati on	None	DSB chartered to examine how DOD certification and qualification processes compare to commercial practices, and whether the benefits are worth the costs. Develops 8 levels of commercial systems (i.e., vast definitions). "Few systems today are military-only – all have some commercial or foreign parts. Very little of what the DOD purchases is also "commercial only;" most systems have been modified in some way to meet military needs" (p. xiii.). Decisions to buy COTS/GOTS are complex. Programs are structured with insufficient flexibility to permit tradeoffs of production schedules with performance and life-cycle costs. Many programs do not adequately integrate systems engineering analysis and programmatic analysis of alternatives early enough to influence decisions and trade-offs. In many cases, "good enough" is also militarily useful. Hence, system usefulness may increase with faster delivery, lower risk, and lower cost. DOD does not understand costs of more customized development (i.e., less COTS) because DOD costing models don't work well for COTS or COTS-based systems. Organizational separation of the technical authority (who can make program decisions) from those responsible for cost and schedule. Technical authorities rarely consider in their test, certification, and qualification processes the implications of efficient, commercial life-cycle sustainment infrastructure. Suppliers change and update products often. "A major cost advantage in the use of many commercial-derivative systems is their adherence to published industry standards." "Use of published industry standards can also speed test, certification, and qualification steps because industry no longer needs to learn, follow, and maintain two or more systems" (p. xv.). Current acquisition practices do not provide DOD contractors incentive to use commercial standards. Some systems integrators use their own proprietary standards. LCS plagued by late adoption of ABS' Naval Vessel Rules which changed technical requirements, ironically, to be more commercial and to allow construction by commercial shipyards. Then, changes to the NVR were made (e.g., ability to access all areas to fight fires). VH-71 was plagued by poor communication between the White House, Navy, Marines, Lockheed, and AugustaWestland which precluded meeting the aggressive schedule. ARH converted from FAA commercial certification to military certification driving costs and delays. The program was cancelled. P-8 used OSA and a commercial platform (Boeing 737). FSF-1 was ABS classification; military certification was not an issue. Ship was launched 29 months from concept. Life-cycle sustainment costs should always be considered in commercial systems. Lessons learned are critical. Case studies should be performed.
57	Baron	2004	Y	Air Force Satellite Control	2 Case Studies based on 34 interviews & 1000+ archival documents	E	Explaining	Knowledge Creation	Org. Behavior	Dissertation byproduct. Case studies of 2 satellite ground control systems with pseudonyms GAMMA (COTS based) and DELTA (mostly non-COTS based). Identifies three organizational barriers to COTS implementation: (1) Misaligned reward system (2) Entrenched networks (3) Historical precedent
58	Baker	2002	N	Air Force T-3	Case Study	C	Analyzing	Disseminati on	None	USAF enhanced flight screening program to replace the T41 (Cessna 172). USAF adopted the COTS Slingsby Aviation (UK) Firefly. The manufacturer upgraded the 200 hp engine to 260 hp, which caused many problems such as stalls, inadequate brakes, weight imbalance, etc., resulting in 131 service/modification bulletins. It was no longer commercial. The T-3A had abbreviated testing – conducted primarily by the contractor's test pilots. Testing occurred at a low-elevation location (Hondo, TX) versus the location of some training at the USAFA. Training was conducted by low-experience instructors. Faulty design/mods resulted in 6 deaths. The 113 planes were grounded permanently in 1999 and scrapped.

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
59	San Miguel et al.	2008	N	Navy Ship Lease	Case Study	E	Analyzing	Disseminati on	None	Examines the Navy's lease (vs. purchase) of 13 commercial-standards maritime prepositioning ships (MPS) for the USMC expeditionary brigades. Proposes four conditions in which leasing support equipment is favorable: (1) When support equipment is mission critical and funding is not available (2) When leasing provides advantages over purchasing (e.g., when the requirement can be fulfilled by COTS products) (3) When timing is critical. (4) Reduced present value of outflows Covers four statutory and regulatory impediments to leasing.
60	Tran	2012	Y	Software Reuse	SEM Survey data *n*=202	E	Explaining & Predicting	Knowledge Creation	TCE, TAM, Info. Sys. Success Model	Dissertation. Examined the success factors of software reuse. IT governance has a positive effect on software reuse success. Relies on the DeLone and McLean IS Success (DMISS) model that consists of six dimensions: information quality, service quality, system quality, intent to use, user satisfaction, and net benefits. The DMISS model is based on based on Shannon's communication theory that entails addresses three levels of concerns in communication: technical, semantic and effectiveness. Software reuse success is comprised of reuse benefits, strategic impacts, and software quality. IT governance (comprised of relational, structural, and process) affects IT strategy and strategic decision-making that, in turn, affect software reuse success.
61	DOD	2000	N	Commercial Item Acquisitions	N/A	C	Analyzing	Disseminati on	None	COTS Lessons learned. "Many DoD requirements must be adjusted to accommodate both the vendor's anticipated uses of the commercial item and the vendor's business practices in order to maximize the item's effectiveness in meeting program needs" (p. 7). "A gap will exist between DoD and commercial use—and the gap may be large." "DoD standards and compliance documents may restrict the use of commercial items" (p. 7). "Modifying the commercial items is not the best way to bridge the gap" (p. 8). "If the gap is too great, commercial items may not be appropriate" (p. 8). "Buy-in from key stakeholders is critical" (p. 8). "Requirement specifications must be flexible and negotiable" (p. 9). "New approaches to program management can enable increased use of commercial items" (p. 9). "Evaluating commercial items in order to identify system tradeoffs is an unfamiliar process for many program managers (and their users)" (p. 10). "It is critically important to evaluate all aspects of a commercial item" (p. 10). "Evaluating various commercial items means comparing things that may not compare very well" (p. 11). "Commercial items are not always commercial off-the-shelf (COTS)" (p. 11). "Even unavoidable tailoring of commercial items can increase program risk." "Incomplete evaluation of commercial items will affect program planning in unexpected ways" (p. 11). "Evaluation will be repeated many times during the life of the system" (p. 12). "A test bed is an excellent mechanism for gaining insight into the design and behavior of a commercial item" (p. 12). A contractor's skill in their knowledge of the marketplace, expertise with specific commercial items, and ability to integrate items will be important considerations in source selection. "Program decisions should reflect total ownership cost" (p. 14). "Vendors' price models are incompatible with familiar DoD cost models" (p. 14). "Key vendors can be strategic partners" (p. 15). "Licenses and data rights define the relationship with the vendor" (p. 15). "Commercial items frequently come with little technical data" (p. 15). "Programs frequently overestimate the impact they can have on vendors" (p. 16). "Consider long-term sustainment before modifying commercial items" (p. 16). "Commercial items can drive the system architecture and design" (p. 17). "Integrating commercial items requires extensive expertise" (p. 17). "Plan for obsolescence and upgrades" (p. 18). "New configuration management techniques are critical" (p. 18).

No.	Author(s)	Year	Scholarly Academic Evidence*	Context	Method	Empirical/ Conceptual	Theory Type (Gregor, 2006)	KM Activity (Beesley & Cooper, 2008)	Theory	Key Findings, Benefits, Lessons Learned, and Best Practices
										“End-user support requires careful consideration” (p. 19). “Extensive program testing of commercial items may be required” (p. 19).
62	Brill	2017	N	Army Battlefield Intelligence System – Distributed Common Ground System-Army (DCGS-A)	N/A	C	Analyzing	Dissemination	None	Explained in detail the Army’s refusal to seriously consider Palantir’s proven battlefield intelligence synthesizing commercial-based software citing allegiance to a bureaucratic acquisition system, an insular defense ecosystem of defense contractors, the Pentagon, and Congress (even with its own surname, the iron triangle), and an organizational separation between the commanders on the ground and the buyers in the Pentagon. Even in the face of prior failure using a legacy acquisition process to acquire the Distributed Common Ground System-Army (DCGS-A) system to meet the same need, the Army would not consider Palantir as a viable option. Instead, the Army ventured on the same path to build upon the failed DCGS-A system. Palantir protested to the U.S. Court of Federal Claims on the grounds that the Army failed to consider commercial items and won its case. The Army refused to consider Palantir’s common ability to tailor its software to suit client needs. A senior defense official attributed the Army’s resistance to adoption of the commercial intelligence synthesis software to insufficient commercial market research.

*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 bias/error is mitigated; describes an appropriate data analysis method

DOD Case Study

Appendix B. COTS Product Appropriateness Scale

Survey Question No.	Survey Question and Scale 1= Strongly Disagree 2= Disagree 3= Somewhat Disagree 4= Neither Agree nor Disagree 5= Somewhat Agree 6= Agree 7= Strongly Agree
1	Considering the degree of fit between end user's needed (or desired) outcomes and the capabilities of the COTS product, the usage of this COTS product is appropriate.
2	Considering the customer's (i.e., end user, technical authority, and program manager) flexibility in needed (or desired) outcomes, the usage of this COTS product is appropriate.
3	Considering the supply-side team's (includes the supplier(s), systems integrator, and program team) experience with the COTS product, the usage of this COTS product is appropriate.
4	Considering the degree of open systems architecture of this COTS product (or the system in which it is integrated, if applicable), the usage of this COTS product is appropriate.
5	Considering the extent of leadership support for the use of this COTS product, the usage of this COTS product is appropriate.
6	Considering the extent of knowledge of the COTS product marketplace that the program team and the systems integrator (if applicable) has (i.e., suppliers, product lifecycle duration, technology roadmap, and update schedule), the usage of this COTS product is appropriate.
7	Considering the extent of stakeholder support for the use of this COTS product, the usage of this COTS product is appropriate.
8	Considering the robustness of the COTS product evaluation and selection process to be used either by the program team or the systems integrator, the usage of this COTS product is appropriate.
9	Considering the planned use of contractual incentives (positive and negative) to motivate contractor COTS product usage, the usage of this COTS product is appropriate.
10	Considering the degree of technical complexity of the use of this COTS product, the usage of this COTS product is appropriate.
11	Considering the program organization's level of resistance to change, the usage of this COTS product is appropriate.
12	A high velocity of COTS product updates makes usage of this COTS product inappropriate.
13	Considering the expected duration of the COTS product's life, the usage of this COTS product is appropriate.
14	Since this COTS product entails a "black box" design, the usage of this

	COTS product is inappropriate.
15	Condsidering the amount of testing to be performed on the COTS product (or the system in which it will be integrated, if applicable), the usage of this COTS product is appropriate.
16	Considering the amount of risk to security introduced by using this COTS product, the usage of this COTS product is appropriate.
17	Our prgram team's inability to manage the COTS product suppliers' intellectual property rights so as to not overly limit the benefits of COTS usage makes the usage of this COTS product inappropriate.
18	Considering our post-adoption COTS product change management preparedness, the usage of this COTS product is appropriate.
19	Considering that the program team will evaluate the total cost of ownership of using the COTS product, the usage of this COTS product is appropriate.
20	Considering the communication plan that ensures information flow and knowledge dissemination among all government and contractor parties, the usage of this COTS product is appropriate.
21	Considering the sufficiency of user training on the COTS product, the usage of this COTS product is appropriate.

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CA 93943

www.acquisitionresearch.net