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14. ABSTRACT Even after repeated high-visibility efforts at reform, the Department of Defense is still to a large extent conducting acquisition as it has for decades. While technology such as big data analytics and artificial intelligence (AI) have become widely prevalent in private industry and are beginning to become more common in some governmental agencies, adoption of these technologies and innovation concerning their possible use is lagging. There is a pressing need in light of the global environment to incorporate AI in both the battlefield and the bureaucracy. Revolutionizing acquisition through the high-end and low-end use of AI could facilitate current and future technologies getting fielded more rapidly. While concerns about AI (such as diffusion, control, and terminology) are valid, we must address and mitigate the risks, push forward with the technologies, and decrease the distance between the scientist and the end-user if the United States is going to prevail in future conflicts.						
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“Artificial Intelligence in Defense Acquisition”

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Gravely Naval Warfare Research Group.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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Stephanie A. Hutchison

Kathryn F. Hutchison

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Introduction

The challenges for the United States (U.S.) around the globe are far-reaching and never ceasing. Addressing these challenges takes determined leadership and an efficient, adaptable, and resilient organization. Over time, that organization – the federal government of the U.S. – has become a vast bureaucracy, at times equally as overwhelming to the veteran as to the neophyte. The size of the military is equally as overwhelming. One can only hope that the force of the U.S. military is as intimidating to our potential adversaries as the military bureaucracy is to its own members!

There is no dearth of military personnel, scientists and engineers, and government leaders working diligently to ensure the U.S. military can take advantage of new technologies such as artificial intelligence, data analytics, and cognitive computing to maintain the U.S.' superiority on the battlefield. This paper, however, will suggest that it is equally as critical for those technologies to be innovatively incorporated and adapted into the highly bureaucratic acquisition system in the federal government as it is into the battlespace – and perhaps into the broader expanse of the federal government, as well. Perhaps, it is even *more* critical. There is no shortage of critics of the Defense Acquisition System. Common concerns include the glacial pace, and the inability of the system to get current technologies to the warfighter without delay. Artificial intelligence and related technologies can be used in a myriad of ways to expedite and improve the acquisition process, thus better equipping our warfighters and maintaining U.S. superiority in future conflicts.

People in many organizations are addressing this concern, but the process will be challenging and will involve assuming technological and even security risks in order to achieve this dramatic leap forward. The reality, however, is that our competitors are already assuming

these risks and taking these steps; therefore, we come closer to losing our competitive edge every day we fail to change the ways we do business.

In the following pages, we will begin by covering a brief explanation of the acquisition system itself, including a brief overview of some of the most common concerns. Following that will be an explanation of the various technologies around and including artificial intelligence (AI), intended to establish a common understanding of the lexicon and terminology being used. Some examples of where these technologies are currently being used in both private industry and in government will be explained, before concluding with recommendations, some challenges already being faced, and a recommendation for further research.

The Acquisition System – A Brief Explanation

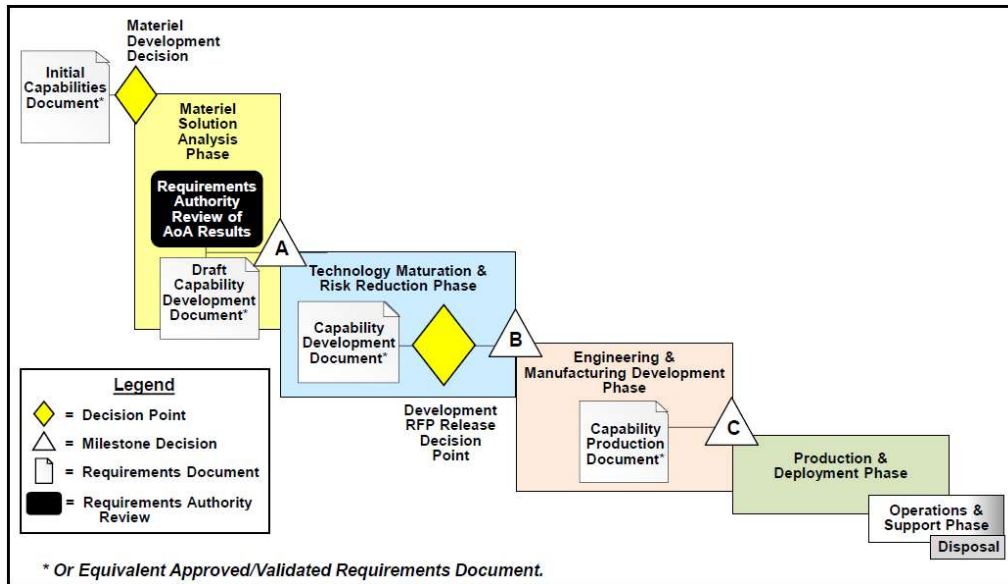
Before discussing how technology can be used to improve the process, it's important to first have a general understanding of the acquisition process. The acquisition process involves three separate processes: the Joint Capabilities Integration and Development System (JCIDS); the Planning, Programming, Budgeting and Execution System (PPBE); and the Defense Acquisition System (DAS). Taken together, these three systems "...form the principal DOD decision support processes for developing and acquiring capabilities required by the military forces to support the national defense strategy."¹ Generally speaking, JCIDS focuses on identifying and defining the requirements needed by the military services, and the PPBE involves the allocation of funding. If the JCIDS process identifies the need for a materiel solution, then the DAS process selects the optimal materiel solution, and oversees development, testing, production, fielding (including sustainment), and even disposal of the selected system.² This

¹ Patrick Wills, "Joint Capabilities Integration and Development System (JCIDS) A Primer," Defense Acquisition University, retrieved on February 16, 2018 from <http://bit.ly/2EssjQD>, slide 4.

² Wills, slide 9.

entire system is sometimes referred to as the “Big A” acquisition process, while the DAS portion is sometimes referred to as “little a” acquisition.³

As you might imagine, navigating this process involves a series of documents, decisions, and milestones. The Capabilities-Based Assessment (CBA) identifies capability gaps that ultimately become requirements. The Initial Capabilities Document (ICD) captures whether a



materiel or non-materiel solution is needed (or combination of the two) to fill gaps identified in the CBA. If a materiel solution is required, a Materiel Development Decision (MDD) is made, and the process enters the Materiel Solution Analysis (MSA) Phase. During the MSA, an Analysis of Alternatives (AOA) is conducted to evaluate the ability of various materiel solutions to fill the capability gaps and takes into consideration cost, schedule, performance, and risk. Upon its completion, the Service, Combatant Command (CCMD), or other agency with the capability gap reviews the AOA results. If approved, a Capability Development Document (CDD) is drafted to capture information needed for development, and the program proceeds to

³ “Joint Capabilities Integration and Development System,” Defense Acquisition University – Acquisition Encyclopedia, retrieved from www.dau.mil, <http://bit.ly/2ELtIKT>.

Milestone A. This marks the beginning of the Technology Maturation and Risk Reduction Phase (TMRR). During TMRR, the CDD is finalized, and a Request for Proposal (RFP) is released to industry to submit proposals to produce the materiel solution. At this point, a contract is awarded to a specific vendor and the program reaches Milestone B, which begins the Engineering and Manufacturing Development Phase (EMD). During EMD, a Capability Production Document (CPD) is written which specifically addresses how the program will be produced. Upon approval of the CPD, the program proceeds to Milestone C, which begins the Production and Deployment Phase. As the system is fielded, the Operations and Support Phase (O&S) occurs, with the Disposal Phase occurring once the system is no longer needed. There can be changes to the length and/or sequence of some of these steps based on whether the program is primarily hardware or software, or even how the program will be fielded.⁴

Any process of this magnitude requires a host of personnel with varying specialties. The Defense Acquisition Executive (DAE) is the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)). The DAE makes the major milestone decisions for the most critical acquisition programs. Component Acquisition Executives (CAE) are each service's senior representative who is responsible for making significant acquisition decisions for their respective services. Program Executive Officers (PEOs) lead groups of programs, while program-specific Program Managers (PMs) have "...responsibility for and authority to accomplish program objectives for development, production, and sustainment to meet the user's operational needs...[and] shall be accountable for credible cost, schedule, and performance reporting to the MDA."⁵ In addition to managers, there are a host of other specialized personnel

⁴ Department of Defense Instruction (DODI) 5000.02, "Operation of the Defense Acquisition System," January 7, 2015, various pages. Graphic on previous page is from DODI 5000.02, page 5.

⁵ Department of Defense Directive (DODD) 5000.01, "The Defense Acquisition System," November 20, 2007, 4.

in the acquisition community, who comprise the Defense Acquisition Workforce. Some of these specialties are Auditing, Cost Estimating (CE)/Financial Management (FM), Contracting, Information Technology (IT), Logistics, Science and Technology Management, and Test and Evaluation (T&E).⁶

The Acquisition System – Problems

“Acquisition reform has been a perennial topic in defense circles for years. We’re wasting billions of dollars, often times on programs that never become operational. But America’s broken defense acquisition system is not just a budgetary scandal. It’s a national security crisis.”⁷

There have been many critics, critiques, and recommendations for improvement of the defense acquisition system over the years. The Congressional Research Office (CRS), the Government Accountability Office (GAO), and a score of think tanks could fill a library with their reports on this important topic. In one report, the following areas were identified which required significant improvements:

- Reduce levels of bureaucracy in the acquisition community
- Attract, retain, and motivate professional, highly-qualified acquisition personnel
- Increase use of Commercial-Off-The-Shelf (COTS) technologies
- Early and regular use of prototyping during product development
- Ensure funding stability
- Increase partnership with the Defense Advanced Research Projects Agency
- Improve data governance.⁸

While you may think this report was written recently, all those recommendations (and others) came from the 1986 Packard Commission Final Report, given to President Ronald Reagan. The chair of that commission was David Packard, one of the founding partners of Hewlett-Packard.

⁶ Defense Acquisition University, <http://icatalog.dau.mil/onlinecatalog/CareerLvl.aspx>.

⁷ Ryan Evans interview with Senator McCain, “5 Questions with Senator John McCain on Defense Acquisition Reform and Drinking with Deng,” www.warontherocks.com, <http://bit.ly/2o83KT3>.

⁸ David Packard, “A Quest for Excellence – Final Report to the President by the President’s Blue Ribbon Commission on Defense Management,” June 1986, xxi-xxvii.

In the years since the Packard Commission's Report, Congress has expended significant effort to legislate improvements to the acquisition system. In 1993 the "Section 800 Panel" assessed defense procurement laws. That was followed quickly by the Federal Acquisition Streamlining Act of 1994 (FASA) and the Federal Acquisition Reform Act of 1996 (FARA). The next decade saw the Services Acquisition Reform Act of 2003 (SARA)⁹ and the Weapons System Acquisition Reform Act (WSARA), enacted in 2009.¹⁰

The last few years have seen even more frequent and significant reforms to the acquisition system, normally legislated through the annual National Defense Authorization Act (NDAA). In fact, over the 2016-2018 time frame, NDAAAs have included a total of 247 articles related to acquisition reform; in the ten years prior to 2016 there were only 477.¹¹ In summary, the legislation included in those three years of NDAAAs focused on the following areas:

- Faster and More Efficient Acquisition
- Major Defense Acquisition Programs (MDAPs)
- Commercial Items
- Data Rights and Intellectual Property (IP)
- Acquisition Workforce
- Roles of Service Chiefs
- Split of USD(AT&L) into Under Secretary of Defense for Research and Engineering (USD(R&E)) and Under Secretary of Defense for Acquisition and Sustainment (USD(A&S))¹²

Remarkably, many of these changes addressed issues which were either the same as those expressed in the 1986 Packard Commission Report or were extremely similar. Some of the

⁹ Marcia G. Madsen, "Report of the Acquisition Advisory Panel to the Office of Federal Procurement Policy and the United States Congress," January 2007, 2.

¹⁰ Defense Acquisition Glossary, "Weapons System Acquisition Reform Act," <https://www.dau.mil/glossary/pages/2890.aspx>.

¹¹ Moshe Schwartz and Heidi Peters, "Acquisition Reform in the FY2016-FY2018 National Defense Authorization Acts (NDAAAs)," Congressional Research Service Report R45068, January 2018, 1-2.

¹² Schwartz, 2-11.

recent legislation actually reversed Packard Commission decisions, including the expanded role of Service Chiefs and the USD(AT&L) split.

The first bullet – “Faster and More Efficient Acquisition” – merits additional discussion, since it seems pertinent to the topic addressed in this paper. In these NDAAs, the ‘acceleration’ of acquisition is accomplished in many cases through the bypassing of legislation, and not through improving efficiency of the full acquisition process. For example, use of “Other Transaction Authority” is expanded for some forms of research and prototyping, which bypasses much of the acquisition timeline. The Defense Innovation Unit – Experimental (DIU-X) uses OTA as one of the ways it gets technology to the warfighter quickly.¹³ Another means by which acquisition is accelerated is by ignoring acquisition policy completely; legislation grants the Secretary of Defense (SECDEF) the right to waive any provision of acquisition policy whenever it is in the vital national security interest of the country.¹⁴

It is important to ensure that even well-intentioned legislation never interferes with ensuring that U.S. servicemembers serve in the best-equipped military in the world. It makes sense, then, that the SECDEF would have the legal right to bypass acquisition policy when the country or her military is at risk. The Defense Acquisition Process, however, is in place for a reason. As convoluted, obtuse, and hard to navigate as it is, the comprehensive process by which military equipment is developed, tested, produced and fielded provides the best means by which our military obtains highly capable, dependable, and maintainable systems with which to fight the country’s wars. It must be a priority, then, to seek ways to accelerate the full acquisition process, instead of legislating ways by which it can be circumvented. Some of the same

¹³ DIU(X) White Paper, “Commercial Solutions Opening – Office of the Secretary of Defense Defense Innovation Unit (Experimental), 2.

¹⁴ Schwartz, 2.

technologies that are being aggressively pushed for use on the battlefield could be used to help improve the efficiency and effectiveness of the acquisition process itself. Improvements in the efficiency of that system will ensure even more advanced and lethal weapon systems will be rapidly fielded, quickly returning the US to a country with increasing power relative to other countries in the world, instead of declining.

From the Abacus to AlphaZero

Whether you believe the first computer was the abacus, the slide rule (1622), Jacquard's Loom (1802-1803) or Charles Babbage's Analytical Machine (1833-1871), it's clear that computing has come a long way.¹⁵ This is particularly true when one discusses deep and reinforcement learning, cognitive computing, and Google DeepMind's AlphaZero. These different generations of technologies have some similarities: even Babbage's machine had a central processing unit, data storage, and a printer. However, what they're capable of is vastly different. In order to intelligently discuss how some of these technologies can be used to revolutionize the defense acquisition process, it's first important to come to a common understanding of the relevant technologies and terminology.

The explosion of computing power is partly due to advances in processing power, data storage, and sensors capable of capturing and digitizing nearly everything about our existence in near real-time. The combination of sensors and data storage has created an idea known as "Big Data," which is used in many different ways. Some people use the term to refer to the quantity of data being collected in today's always-connected culture. Others use it to refer to a process:

"Big data refers to a process that is used when traditional data mining and handling techniques cannot uncover the insights and meaning of the underlying data. Data that is unstructured or time sensitive or simply very large cannot be

¹⁵ William Harris, "Who Invented the Computer," <https://science.howstuffworks.com/innovation/inventions/who-invented-the-computer1.htm>.

processed by relational database engines. This type of data requires a different processing approach called big data...”¹⁶

Whether discussing the systems, the technologies, or the processes, “big data” involves a nearly infinite amount of wildly disparate data, which when valid can be of significant use. In fact, many people summarize this concept through the “4 Vs” of Big Data: volume, variety, velocity, and veracity.¹⁷

Big Data is critical in another emerging field: analytics, which can be general or predictive. Analytics involves the process of using Big Data to “uncover...insights and meaning...”¹⁸ either about current trends or about the future. The process of reviewing such an enormous quantity of data for analytics, however, has exceeded the capability of human beings to accomplish with any efficiency. In many cases, organizations are turning to Artificial Intelligence (AI) to assist with this process.

AI can be defined or explained in many different ways. A definition from the 1981 book, “The Handbook of Artificial Intelligence,” states:

“Artificial Intelligence (AI) is the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior – understanding language, learning, reasoning, solving problems, and so on.”¹⁹

AI evokes passionate debate amongst many different communities of people. Examining the nuances of this debate, which often includes a fear of computers running the world, is beyond the point of this research. The underlying reason for this concern, however, is important to

¹⁶ Definition of “Big Data” retrieved from www.techopedia.com. For consistency, additional definitions of other technologies will also be drawn from this source. <https://www.techopedia.com/dictionary>.

¹⁷ IBM Big Data and Analytics Hub, retrieved February 18, 2018, <http://www.ibmbigdatahub.com/infographic/four-vs-big-data>.

¹⁸ www.techopedia.com/dictionary.

¹⁹ Avron Barr and Edward A. Feigenbaum, “The Handbook of Artificial Intelligence – Volume 1,” HeurisTech Press, Stanford University, retrieved from <https://archive.org/stream/handbookofartific01barr#page/n19/mode/2up>, 3.

understanding the technologies and their potential application in acquisition. AI has many different levels of ‘intelligence’: Artificial Narrow Intelligence (ANI), Artificial General Intelligence (AGI), and Artificial Super-Intelligence (ASI). ANI is considered commonplace today, from Alexa, to Siri, to Amazon’s recommendations for what else you need to buy based on your previous purchases. It is created to accomplish tasks in one specific area. AGI, however, is where many people begin to get concerned. When computers are capable of AGI, they will have reached a processing level approximately equal to human-level intelligence. The predominant belief is that once a computer reaches AGI, the exponential learning curve will basically become vertical as the computer’s learning capabilities are limited only by processing capability. This will lead to ASI, which “ranges from a computer that’s just a little smarter than a human to one that’s trillions of times smarter—across the board.”²⁰

AI (at this point limited to ANI) is becoming so commonplace in our society that its prevalence has created what’s been called the “AI Effect.” In essence, as people get more comfortable with AI in their life, they come to see it as just more complicated computer programming, instead of AI.²¹ Amazon’s Alexa is a good example. With its ability to comprehend natural language and scan vast quantities of data, it’s a good example of ANI. (This makes Alexa an example of an Intelligent Agent (IA).²²) However, it’s a relatively simple use of AI involving Machine Learning (ML). ML is capable of much more than what’s demonstrated by your daily interactions with Siri or Alexa, however. “[ML] provides the ability to automatically obtain deep insights, recognize unknown patterns, and create high performing

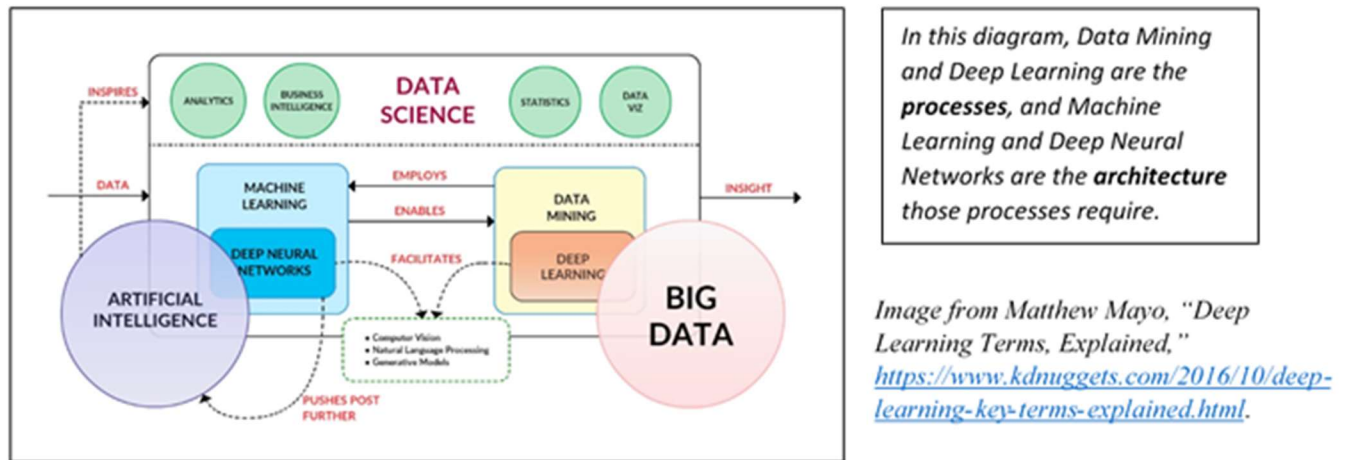
²⁰ Tim Urban, “The AI Revolution: The Road to Superintelligence,” <https://waitbutwhy.com/2015/01/artificial-intelligence-revolution-1.html>.

²¹ Alex Castrounis, “Artificial Intelligence, Deep Learning, and Neural Networks, Explained,” <https://www.kdnuggets.com/2016/10/artificial-intelligence-deep-learning-neural-networks-explained.html>.

²² Seth Earley, “My Alexa Experience – “Physical Dimensions” versus “Dimensions”,” <http://www.earley.com/blog/lessons-alex-artificial-intelligence-and-machine-learning-use-cases>.

predictive models from data, all without requiring explicit programming instructions.”²³

Computers using ML are able to accomplish these tasks through the use of extremely



complicated algorithms (defined as “a predetermined set of instructions for solving a specific problem in a limited number of steps”²⁴). The ability of ML to recognize insights and conduct predictive analytics is what makes it so useful in the analysis of Big Data.

A very specialized form of ML uses Artificial Neural Networks (ANNs), which mimics the operation of the human brain. At an extremely high level, neural networks involve layers of artificial neurons: an input layer, at least one hidden layer, and an output layer. Through the use of algorithms, when the computer receives enough inputs it completes a transaction to ‘leap’ to the hidden layer, then to the output layer. The existence of the hidden layers makes it impossible to reconstruct with certainty why a computer using ANNs made a certain decision. This makes the use of ANNs a “Black Box algorithm” since human can’t explain why the AI made a certain decision. In some cases, ANNs can’t be used since the ability to provide that explanation is necessary. For example, when a credit application is denied by a bank’s AI and the customer

²³ Alex Castrounis, “Machine Learning: An In-Depth Guide - Overview, Goals, Learning Types, and Algorithms,” https://www.innoarchitech.com/machine-learning-an-in-depth-non-technical-guide/?utm_source=innoarchitech&utm_medium=post&utm_content=chapterlink&utm_campaign=blog.

²⁴ Webster’s New World College Dictionary – Fifth Edition, Houghton Mifflin Harcourt, Boston, 2016.

appeals, the bank needs to be able to explain why the decision was made; this is not always possible when ANNs are used.

Deep Learning (DL) is a learning process for AI which involves more than two hidden layers; when more than ten hidden layers are used, it's considered "very deep learning."²⁵ The term DL is actually derived from the fact that the addition of hidden layers makes the neural network physically *deeper*. Gregory Piatetsky-Shapiro tied the three concepts of AI, ML, and DL together with this explanation: "If AI can be compared to a car, then Machine Learning is its engine, and Deep Learning is just one type of engine."²⁶

Cognitive computing actually builds on neural networks and DL and uses cognitive sciences to enable computers to more closely resemble the actual way humans think. It involves a number of fields including ML, natural language processing (NLP), image recognition, and human-computer interaction. IBM's use of Watson to play the well-known game show Jeopardy is an early example of cognitive computing.²⁷

Perhaps the best way to illustrate these levels of AI and ML/DL is to walk through a number of well-publicized uses of the technology. In 1997, Garry Kasparov, chess Grandmaster, was defeated by IBM's Deep Blue chess-playing super computer 3 ½ games to 2 ½.²⁸ However, this was not AI. Deep Blue simply used processing power to evaluate 200 million chess positions per second, and a repository of a century of opening moves by other chess grandmasters to logically determine the correct move.²⁹ When IBM's descendant computer,

²⁵ Alex Castrounis, "Artificial Intelligence, Deep Learning, and Neural Networks, Explained," <https://www.kdnuggets.com/2016/10/artificial-intelligence-deep-learning-neural-networks-explained.html>.

²⁶ Matthew Mayo, Is "Artificial Intelligence" Dead? Long Live Deep Learning?!?," <https://www.kdnuggets.com/2016/08/artificial-intelligence-dead-long-live-deep-learning.html>.

²⁷ M. Tim Jones, "A beginner's guide to artificial intelligence, machine learning, and cognitive computing," <https://www.ibm.com/developerworks/library/cc-beginner-guide-machine-learning-ai-cognitive/index.html>.

²⁸ "May 1997: Deep Blue Beats Kasparov," <http://www.history.com/this-day-in-history/deep-blue-beats-kasparov>.

²⁹ "Frequently Asked Questions: Deep Blue," <https://www.research.ibm.com/deepblue/meet/html/d.3.3a.html>.

Watson, appeared on Jeopardy in 2011, it used true AI in its victory. IBM used a system called DeepQA (Question and Answer) in Watson which was capable of ML. It gave Watson the ability to rapidly deconstruct the words in the ‘answer,’ review over 200 million pages of information to develop a number of possible ‘questions,’ assess reliability and relevance, determine a probability of accuracy, and then respond.³⁰ This well-publicized example of cognitive computing and use of ML went beyond simple ‘if-then’ decision trees into understanding nuances of the language and making correct choices based on a vast collection of data. Since then, Watson has advanced even more and is now well-known for using its cognitive computing skills to do work in the medical field, business, and even entertainment³¹; recently, Watson generated a complete movie trailer for the 21st Century Fox AI-horror thriller “Morgan” with no human assistance; the only input it was provided was the full film.³²

Some of the leading AI, ML, and DL work today is being accomplished by the London-based company DeepMind, which was acquired by Google in 2014.³³ DeepMind may be most well-known outside of the tech world for creating the Go-playing computer, AlphaGo. Once computers were regularly defeating human players in chess, Go was seen as the ‘holy grail’ test for AI. To give you an idea of the magnitude of difference between the games, after the first two moves of a game of chess, there are 400 possible next moves; in Go, there are nearly 130,000. Part of AlphaGo’s training was the uploading of 30 million moves by master Go players; in this way, it was similar to DeepBlue. However, AlphaGo was then trained to learn from itself: it

³⁰ Jo Best, “IBM Watson: The inside story of how the Jeopardy-winning supercomputer was born, and what it wants to do next,” <https://www.techrepublic.com/article/ibm-watson-the-inside-story-of-how-the-jeopardy-winning-supercomputer-was-born-and-what-it-wants-to-do-next/>.

³¹ Will Knight, “IBM’s Watson Is Everywhere—But What Is it?,” MIT Technology Review, <https://www.technologyreview.com/s/602744/ibms-watson-is-everywhere-but-what-is-it/>.

³² “Morgan | IBM Creates First Movie Trailer by AI [HD] | 20th Century FOX,” <https://www.youtube.com/watch?v=gJEzuYynaiw&t=11s>.

³³ “The Company,” <https://deepmind.com/about/>.

combined a complex algorithm with a 12-layer neural network to run through all the possible moves, select the preferred move, and then predict the winner. In March of 2016, AlphaGo defeated Lee Sedol, one of the world's greatest Go players.³⁴ Although a valid example of AI and DL, even that recent technology is now outdated when compared to DeepMind's newest Go player, AlphaGo Zero. AlphaGo Zero uses Reinforcement Learning (RL), with which it was able to achieve the following results:

- Beat the previous version of AlphaGo (Final score: 100–0).
- Learn to perform this task from scratch, without learning from previous human knowledge (i.e. recorded game play).
- World champion level Go playing in just 3 days of training.
- Do so with ~90% fewer neural networks.³⁵

What is truly remarkable – or perhaps, frightening – is the second bullet: AlphaGo Zero did not have the benefit of 30 million games played by human players. AlphaGo Zero “started from scratch with just the rules of Go programmed.”³⁶ This is accomplished through RL, which means the computer plays games against itself, learns from its mistakes or winning strategies in each game, and becomes a better player with each successive game. Also, because the computer begins *tabula rasa* (“blank slate,” or with no knowledge of previous games) it is not limited by previous human strategies, so can theoretically develop strategies which are incomprehensible to humans.³⁷

The latest work by DeepMind, and along the progression of AI and DL/RL, is their development of AlphaZero, described as “a similar but fully generic algorithm...[which demonstrates] that a general-purpose reinforcement learning algorithm can achieve, *tabula rasa*,

³⁴ Danielle Muoio, “Why Go is so much harder for AI to beat than chess,” <http://www.businessinsider.com/why-google-ai-game-go-is-harder-than-chess-2016-3>.

³⁵ Carlos E. Perez, “Why AlphaGo Zero is a Quantum Leap Forward in Deep Learning,” <https://medium.com/intuitionmachine/the-strange-loop-in-alphago-zeros-self-play-6e3274fcdd9f>.

³⁶ Ibid.

³⁷ “AlphaGo Zero: Learning from scratch,” <https://deepmind.com/blog/alphago-zero-learning-scratch/>.

superhuman performance across many challenging domains.” There were several major differences between AlphaGo Zero and AlphaZero: AlphaZero continuously learns during games, instead of at the end of each game; it allows for non-binary conclusions; and it uses general and not game-specific parameters in its algorithms and networks.³⁸ In December of 2017, AlphaZero defeated Stockfish, elmo, and AlphaGo Zero, the world-champion programs in the games of Chess, Shogi (a form of Japanese Chess), and Go, respectively. Using a vast number of tensor processing units (TPUs) for self-play, AlphaZero trained its neural networks to play each of these three games – *using the same algorithm for all three*.³⁹

As with any set of emerging technologies that is only truly understood by a small percentage of the population, the explanations here are only intended to facilitate a discussion. It is meant to illustrate interrelationships between these technologies, as well as provide a general understanding. This understanding is pivotal to the next discussion of how these technologies are being used in industry and government today, and finally, how they could be used to improve defense acquisition.⁴⁰

Technology in Industry

These technologies are being rapidly adopted and innovatively used across private industry. IBM’s Watson is perhaps on the best and longest-known examples of AI and has received a significant amount of media attention for its use in the medical field. Unfortunately, though, not all those cases have achieved the intended results. In 2013, the MD Anderson

³⁸ David Silver, Thomas Hubert, and Julian Schrittwieser, “Mastering Chess and Shogi by Self-Play with a General Reinforcement Learning Algorithm,” Cornell University Library, retrieved from <https://arxiv.org/abs/1712.01815>, 1-2.

³⁹ “AlphaZero,” <https://en.wikipedia.org/wiki/AlphaZero>, retrieved February 19, 2018.

⁴⁰ For additional independent research on these topics, I highly recommend IBM and Google DeepMind’s websites, along with kdnuggets.com and innoarchitech.com.

Cancer Center at the University of Texas worked with Watson to diagnose and even propose possible treatments for cancer. By 2017, \$62 million had been spent on the project, and it had yet to diagnose a single patient; as a result, the project was put on hold. Ironically, though, cognitive computing and artificial intelligence are still being used with great success: it's currently being used for jobs such as "making hotel and restaurant recommendations for patients' families, determining which patients needed help paying bills, and addressing staff IT problems."⁴¹ Each of these uses has led to improvements and costs savings. In a recent study of 152 AI-related projects, the projects which were intended to implement extremely advanced technologies or higher-end AI were typically much less successful than "low-hanging fruit" projects.⁴² The development of AI has led to an explosion of companies exploiting this technology for both high and low-end uses.

One example is SoundHound, a company which focuses on building a voice assistant exponentially more powerful than the Siris and Alexas with which we're familiar. By using AI which can understand both language in context (i.e., normally spoken language) and voice recognition into a single step, SoundHound can answer questions such as "Show me all below-average-priced restaurants within a five-mile radius that are open past 10 p.m. but don't include Chinese or pizza places."⁴³ A more common form of AI such as Alexa would have trouble answering such a complex query.

Spoke is a company using AI to assist companies with answering relatively basic questions from employees. Employees can submit questions via Slack, in the Spoke app, or by

⁴¹ Thomas H. Davenport and Rajeev Ronanki, "Artificial Intelligence for the Real World," Harvard Business Review, Jan-Feb 2018, 108-110.

⁴² Davenport, 110.

⁴³ Kevin J. Ryan, "5 Artificial Intelligence Companies to Watch in 2018," <https://www.inc.com/kevin-j-ryan/artificial-intelligence-companies-to-watch-in-2018.html>.

text or email. Questions could concern any aspect of internal operations, from requests for Information Technology (IT) computer support, to questions about days off, to reporting problems with the building or facilities, such as lights being out or broken furniture. The system automatically provides a reply to the employee, and also routes the question, complaint, or comment to the correct department.⁴⁴

Another start-up called Voicera has introduced a virtual assistant for meetings called “Eva,” which stands for Enterprise Voice AI. Eva listens to meetings, transcribing the full text of the meeting, and then produces highlights which can then be e-mailed to meeting participants or members of the organization. Eva can also be called upon in the meeting to specify action items for the transcription or highlight key words or passages.⁴⁵

Google has put their ML technology to use potentially saving them hundreds of millions of dollars annually. The data centers operated by Google are huge and use a tremendous amount of electricity to power the air conditioning units needed to cool the computers. Demand is always changing in the data centers which means that there are certain times when more heat is generated, requiring more cooling to maximize efficiency. Google used ML to predict how much air conditioning would be needed, and automatically change the air flow as needed. This is expected to make the cooling units 40% more effective, cutting the data centers’ energy consumption by 15%. When one considers that it is estimated that Google’s data centers use 0.01% of the world’s electricity, that’s a significant savings.⁴⁶

⁴⁴ Ibid.

⁴⁵ “Startup Builds AI System To Transcribe Meetings,” <https://news.developer.nvidia.com/startup-builds-ai-system-to-transcribe-meetings/>.

⁴⁶ Sam Shead, “Google’s \$500+ million purchase of DeepMind just got very interesting,” <http://www.businessinsider.com/googles-400-million-acquisition-of-deepmind-is-looking-good-2016-7?r=UK&IR=T>.

Another company completely predicated on the use of AI is Legal Robot. One of their products performs Contract Analytics, which can “[a]utomatically extract key business terms...[and] compare documents and securely collaborate with your legal team.”⁴⁷ Legal Robot is also working on a product which can interpret complex legal documents, and present the information in less complex terms, even using visualizations.⁴⁸ More recently, an Israeli firm called LawGeex released the results of a study during which its DL algorithm was pitted against 20 human lawyers in the review of five non-disclosure contract agreements. The study showed that the computer achieved an accuracy level of 94% against the lawyers’ accuracy level of 85%, and accomplished the reviews in 26 seconds, while the lawyers took an average of 92 minutes.⁴⁹

H&R Block is another company taking advantage of AI. H&R Block has partnered with IBM’s Watson for use during individual tax preparation to ensure the maximum tax refund is received. Watson uses AI and its cognitive computing capabilities to access all 74,000 pages of the U.S. Tax Code, constant legislative changes, and the experience gained from its previous tax preparation work to maximize deductions and thus the tax refund for each individual. The constant changes to the immense tax code and relevant laws makes it impossible for a human, regardless of their level of experience, intellect, or years in the industry to match Watson’s capabilities – but H&R Block still uses a person with Watson to prepare a client’s taxes.⁵⁰

Harvard Business Review recently highlighted Proctor & Gamble and American Express as two companies that have been focused on the use of AI in their companies for a long time and continue to focus on innovation in this area today. American Express was using an expert system called Authorizer’s Assistant in the 1980s to assist human advisers in whether or not

⁴⁷ “Products,” <https://www.legalrobot.com/products/>.

⁴⁸ Ibid.

⁴⁹ “AI vs Lawyers,” <https://www.lawgeex.com/AIvsLawyer/>.

⁵⁰ “Why leave even one precious cent on the table?,” <https://www.ibm.com/watson/stories/hrblock/>.

large charges should be approved by cardholders. Both of these companies have leaders committed to a focus on big data and analytics in cognitive computing, and also understand the need to have organic computer programmers and data scientists.⁵¹ As of May 2017, American Express had about 56,000 employees⁵², and 1,500 data scientists!⁵³ The article goes on to say that both companies are dedicated to the use of these technologies for both clients as well as their own internal business operations. For example, P&G uses AI in a Olay Skin Advisor app, which provides recommendations for skin care products for people based on a selfie, but also uses these technologies for customer service and logistics management.⁵⁴

Academia has long recognized the importance and relevance of AI in new product development. In a paper from the Journal of Intelligent Manufacturing from 1999, the authors wrote "...artificial intelligence and expert systems can play an important role in manufacturing by reducing product development times, improving quality, and reducing costs."⁵⁵ The paper describes how product development can be accomplished linearly, with tight control by supervisors through a "stage gate system,"⁵⁶ which very closely parallels the Defense Acquisition System. It also states that to remain successful, many companies are transforming to a concurrent engineering model, where phases such as concept generation, product planning, engineering, and testing overlap⁵⁷; again, this is similar to some of the recent NDAA authorizations for modifications of the acquisition system to accelerate the development and

⁵¹ Thomas H. Davenport and Randy Bean, "How P&G and American Express are Approaching AI," <https://hbr.org/2017/03/how-pg-and-american-express-are-approaching-ai>.

⁵² "America's Best Employers for Diversity," <https://www.forbes.com/companies/american-express/>.

⁵³ Davenport.

⁵⁴ Ibid.

⁵⁵ S. Subba Rao, Abraham Nahm, Zhengzhong Shi, Xiaodong Deng, and Ahmad Syamil, "Artificial Intelligence and expert systems applications in new product development – a survey," Journal of Intelligent Manufacturing (10), 1999, 232.

⁵⁶ Rao, 232.

⁵⁷ Rao, 233.

introduction of systems into the battlespace – but tragically, almost 20 years after private corporations were already shifting to this model.

Current Governmental Efforts

Fortunately, some sections of the Department of Defense and other areas of the federal government are starting to reform how they do business through the incorporation of some of these new technologies, and recent reports indicate that more steps may be proposed – and hopefully adopted – in the near future.

The Government Services Administration (GSA) is perhaps not perceived by the public as a paragon of emerging technology. Basically, the GSA manages and preserves government buildings by leasing and managing commercial real estate, offers private sector services and supplies to the government, and promotes efficient government.⁵⁸ Similar to the defense acquisition system, operations at GSA are regulated by a tremendous amount of onerous laws and federal regulations, as well as involve contracting. Recently, GSA built the first federal procurement system which uses blockchain technology.⁵⁹ This proof of concept was developed in only seven weeks, and by combining blockchain, AI and robotics reduced the average time needed to award contracts from 100 days to less than ten. This system eliminated human errors, conducted a thorough review of the bidding companies' financial health, and complied with all government regulations and laws, while providing transparency to the government and bidding

⁵⁸ www.gsa.gov/about-us.

⁵⁹ A 2017 Harvard Business Review article about blockchain (Marco Iansiti and Karim R. Lakhani, "The Truth About Blockchain," hbr.org/2017/01/the-truth-about-blockchain) defined it as "...an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way...[where] contracts are embedded in digital code and stored in transparent, shared databases, where they are protected from deletion, tampering, and revision."

companies.⁶⁰ A ten percent reduction in the time required to sign contracts in the acquisition community would revolutionize the acquisition system.

Even more recently, GSA announced the publishing of a monthly report called “EmergingTech Check,” intended to synchronize governmental efforts on the use of emerging technologies. Justin Herman, the head of GSA’s Emerging Citizen Technology Office, stated: “Nobody knows the full breadth of what’s going on...[T]hings are happening quickly, there’s no real centralization, and there’s not a lot of reporting structures that really move at the speed...we need.”⁶¹ GSA has correctly identified that the efforts being made in different areas of government must be aligned and supporting each other to prevent duplicate unnecessary effort.

In another area of the government, IBM’s Watson is being called upon by the United States Air Force to assist with acquisition specifically. After reaching the conclusion that no human, no matter how intelligent, can be aware of every facet of the Federal Acquisition Regulation (which they call “1,897 pages of the densest prose on the planet.”⁶²) they asked contractors to develop an AI-based system to help government employees and potential contractors navigate the acquisition process. Camron Gorguinpour, a senior official in the Air Force acquisition office, stated that defense procurement is perfect for the capabilities of Watson since it’s a formal albeit extremely complicated process. The transparency and ease of use will make it easier for many small businesses to bid on government contracts. Some of these companies may have previously not bid due to the complicated government acquisition process.

⁶⁰ Stefaan Verhulst, “Blockchain Slashes US Govt. Contract Award Time From 100 To 10 Days,” www.thegovlab.org/blockchain-slashes-us-govt-contract-award-time-from-100-to-10-days/.

⁶¹ Jack Corrigan, “GSA Is Giving a Bird’s Eye View of Emerging Government Tech,” <https://www.nextgov.com/emerging-tech/2018/04/gsa-giving-birds-eye-view-emerging-government-tech/147373/>

⁶² Christian Davenport, “The Pentagon’s procurement system is so broken they are calling on Watson,” <https://wapo.st/2vQuT2Y>.

Perhaps most importantly, Jason Summers, one of the engineers from Applied Research in Acoustics who is working with the Air Force on this project, stated that this technology is best employed with a human partner – “It’s the perfect task for human-machine teaming”⁶³

The Army is also looking at how emerging technologies can be used to improve acquisition. Although not quite so advanced as the Air Force’s efforts, their efforts have already saved the Army approximately \$5 billion and increased the combat power per dollar by 30%. In a partnership with Sandia National Laboratories, the Army created a system called the Capability Portfolio Analysis Tool (CPAT) which used sophisticated optimization software with useful visualization products to compare alternative investment strategies. The Army used CPAT to decide whether to invest in the Ground Combat Vehicle (GCV) to replace the Bradley Fighting Vehicle (BFV) or invest in modernization of existing systems. Along with performance, financial, and schedule details of all the options, CPAT used 40 business rules, 70,000 constraints, 8,000 integer variables, and 2,000 binary variables as it compared the options. As one officer stated, “Acquisition has to depend on more than the opinions of people in the room.”⁶⁴ Ultimately, CPAT shocked many in the Army by providing a solution which generated more combat power than the Army’s previous plan, even after factoring in a 25% budget cut which the previous Army plan had not. CPAT’s impressive capabilities resulted in the Army extending its use to other major programs. Additionally, the Secretary of the Army has directed that those programs be continuously evaluated across a 30-year timeline for optimization of

⁶³ Christian Davenport, “The Pentagon’s procurement system is so broken they are calling on Watson,” <https://wapo.st/2vQuT2Y>.

⁶⁴ “U.S. Army’s Future Contribution to Global Security using the Capability Portfolio Analysis Tool,” <https://www.youtube.com/watch?v=2-tQ-mNFF-E>.

acquisition and investments, since CPAT can so readily weigh all the variables even on that extended timeline.⁶⁵

Recommendations / The Way Ahead

Unfortunately, uses of technology such as these are rare in the federal government and defense acquisition. While many organizations and individuals are focused on the use of AI for the warfight itself, there is much less discussion about how technologies could immediately be integrated into the bureaucracy of the acquisition system across the Department of Defense. In fact, it would be logical for these technologies to be integrated everywhere that the Federal Acquisition Regulation (FAR) applies, across the whole of the federal government.

One of the most urgent needs for the government is the hiring of data scientists and experts in artificial intelligence and related fields. During an interview with Mr. Brock Christoval, a data scientist from Naval Surface Warfare Center – Corona who is temporarily assigned to Naval Sea Systems Command (NAVSEA), he listed several areas where the incorporation of new technologies could be used to benefit the acquisition process. As an interesting side note, he also tellingly mentioned that the Office of Personnel Management doesn't even have a manpower classification for the position of Data Scientist! Currently Mr. Christoval is the only data scientist at NAVSEA – and he's on a temporary assignment.⁶⁶ In our discussion, he stressed the importance of hiring more people in these areas – computer science and big data, specifically – to integrate with the acquisition community. Hiring data scientists and computer programmers who have experience in AI, big data, and data analytics to become familiar with the acquisition organization and processes, integrate with the different offices and

⁶⁵ "U.S. Army's Future Contribution to Global Security using the Capability Portfolio Analysis Tool," <https://www.youtube.com/watch?v=2-tQ-mNFF-E>.

⁶⁶ Mr. Brock Christoval (NSWC Corona Data Scientist) in discussion with the author, February 18, 2018.

teams, and then make recommendations for where these technologies could be integrated would have the potential to lead to rapid adoption of new technologies. This would certainly result in dramatic changes to archaic processes with unprecedented improvements in efficiency.

Another urgent need is to change policies related to integration of current technology into and onto government computer networks. Government computer networks are significantly outdated and have fallen far behind private industry. This not only prevents communication in many ways between the federal government and private industry, but also prohibits interoperability between new technologies and government networks. While transfer of these technologies onto a classified network would undoubtedly be more involved, modifying policies and regulations on the unclassified networks to support use of some of these technologies, while still maintaining appropriate and necessary security protocols, is possible. The modification of the policies regarding what software is approved for use on the networks could accommodate many of the technologies presented earlier and would result in significant process improvement across the organization.

As an example, take the earlier explanations of Spoke, Voicera, LawGeex, and H&R Block's work with Watson. Spoke could be used for facilities, human resources, and information technology questions, many of which could be handled with minor human involvement and significantly improve efficiency and employee satisfaction. Voicera could be used for the myriad of constant meetings, up to and including milestone decision review meetings, which are held throughout the entirety of the acquisition process. The ability for the real-time transcript and highlights (including decisions) to be delivered to stakeholders, present or not, would dramatically decrease the time taken to both produce, distribute, and have that information reviewed. The technology used in LawGeex and Legal Robot could be used to assist

Contracting Officers with the review of contracts submitted. Mr. Christoval stated that contracts can take nine months to be reviewed and signed; the automation of the mechanistic aspect of contract reviews could drastically reduce the time required and allow the contracting officers to reallocate saved time to the most contentious issues and inter-personal cooperation with stakeholders. Incorporation of the blockchain system created for use at GSA could reduce this notional nine-month contract award example to less than a month. Finally, the wholesale adoption and implementation of a Watson-type AI for use by all members of the acquisition community, as demonstrated by the Air Force, would immediately give each member of the acquisition community real-time access to every nuance of the FAR and DFARS, up to and including real-time legislative changes. This tool alone would truly revolutionize acquisition – not by replacing the people, but by giving each member of the acquisition community, regardless of experience or tenure, the ability to harness technology appropriately and focus their efforts and time on more complex situations warranting human consideration.

GSA has identified another needed change: the alignment and sharing of ideas concerning incorporation of these technologies across the government. Specifically in the defense acquisition community, it is clear that Army has had success with CPAT and Air Force is leaning forward with the use of Watson. Sadly, however, there is no indication of information sharing between the services. Through the course of my research, including the conduct of multiple interviews, it is evident that there is no common vision to advance the incorporation of AI. While many independent efforts are being made, there needs to be a single organization identified as the synchronizer of AI efforts across the DoD, and perhaps the federal government. To achieve this, an office inside the Office of the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) must be created to specifically focus on Artificial Intelligence.

While part of the responsibilities of that office may be development, with its own organic team of scientists and programmers, it would also be to align the efforts of the many other organizations across the military. This office would implement the concept embodied in GSA’s EmergingTech check monthly report. Additionally, it would be focused on the utilization of AI-related technologies both in the warfighting arena and in the bureaucracy. After all, as the MD Anderson Cancer Center discovered, AI can be used to help solve many problems, but the quickest and most tangible return on investment may be on relatively mundane management tasks – and acquisition is a perfect fit. (Coincidentally, on May 10, 2018, Michael Kratsios, who is currently serving as the head of the Office of Science and Technology Policy, announced the creation of a Select Committee on Artificial Intelligence. This new organization appears poised to address the recommendation outlined here. This committee will include some of the leading AI researchers in the federal government, and facilitate cross-governmental AI efforts, as well as work to improve relationships between the federal government, private industry, and other researchers.⁶⁷)

Challenges

Technological Diffusion (Tech Diffusion)

One of the most significant challenges to the adoption of these technologies is why new technologies such as AI slow to be adopted, and how they are diffused, or spread, throughout an organization or culture. Dr. Thomas Choinski addresses this in his dissertation, “Dramaturgy, Wargaming and Technological Innovation in the United States Navy: Four Historical Case Studies.” In his paper, Dr. Choinski introduces a concept he calls ‘technological aliasing,’ which

⁶⁷ Aaron Boyd, “White House Announces Select Committee of Federal AI Experts,” <https://www.nextgov.com/emerging-tech/2018/05/white-house-announces-select-committee-federal-ai-experts/148123/>.

addresses a lack of alignment between communities involved in the development of new technologies, and the communities who will ultimately use those technologies.⁶⁸ In his explanation of the concept, he references four specific groups earlier identified by Kline: scientists, engineers, policy-makers, and end-users. The frequent lack of alignment between these four groups is the problem of technological aliasing.⁶⁹

Sadly, this problem has always been common in the military, as in many organizations. There are significant gaps between the designers and scientists at organizations such as the Defense Advanced Research Projects Agency (DARPA), the engineers at places such as the Naval Warfare Centers, the policy-makers in Washington, DC, and the end-users in the fleet. As this gap widens, the scientists and engineers become more and more detached from what is needed by the end-users in the fleet. In an interview with Dr. Yvonne Masakowski, she acknowledged this detachment, and stated that getting new technologies out of the laboratory and into the hands of end-users is of critical importance. As she said, “End-users come up with some of the best feedback, and innovative needs and uses.”⁷⁰ Closing this gap will also prevent the dangerous problem of scientists believing they are meeting end-users’ needs, but in reality are only meeting the needs of the policy makers.

In an interview with Dr. Choinski, he confirmed the existence of this disconnect, and also pointed out that science and technology in the military can move quickly, but often acquisition is the “valley of death,” significantly increasing the delay for those technologies to get to end-users. In his estimation, several changes must be made to minimize tech aliasing and get the right

⁶⁸ Dr. Thomas Choinski, “Dramaturgy, Wargaming and Technological Innovation in the United States Navy: Four Historical Case Studies” (PhD dissertation, Salve Regina University, 2017), 56.

⁶⁹ Choinski, 59-60.

⁷⁰ Dr. Yvonne Masakowski (U.S. Naval War College Associate Professor of Strategic Leadership and Leader Development) in discussion with the author, March 5, 2018.

technology to the end-users more quickly. First, tools or processes need to be put in place to ensure that the first three communities – designers, engineers, and policy-makers – are getting candid and timely feedback from end-users. Second, the speed of the innovation cycle must be accelerated, from analysis, to concept development, to experimentation and wargaming, and back to analysis. The more robust adoption of advanced technologies such as AI can and should assist with this change. Finally, we need to improve the pace and accuracy with which we develop doctrine for the use of new technologies, another problem which can be addressed through the improvement of communication between all communities.⁷¹

In a conversation with Mr. Martin Kruger from the Office of Naval Research, he pointed out that current operational demands on the fleet make it difficult for scientists to involve end-users in the development of new technologies.⁷² While operational demands on fleet units are real, it's critical that the Navy and Department of Defense as a whole understand the potentially existential need for scientists and engineers to frequently engage with end-users in the fleet. If technological aliasing and the innovation cycle time are not severely minimized, the gap between what the fleet needs and what resources are spent developing and acquiring will only widen. Leaders in the acquisition community are at the nexus of all these communities, and thus are in the best position to innovate in this area and look for solutions.

Terminology

Although not restricted to the acquisition community, federal government, or even artificial intelligence, over the course of this research it's become clear that to intelligently advance these technologies, it's important to clearly define both what the technologies are, and what the terms mean that are used to describe them. In the earlier section "From the Abacus to

⁷¹ Dr. Thomas Choinski (NUWC Deputy Director) in discussion with the author, March 2, 2018.

⁷² Mr. Martin Kruger (Office of Naval Research) in discussion with the author, April 9, 2018.

AlphaZero,” the author attempted to provide a general understanding of the technologies themselves. What’s also needed, however, is a clear and common understanding of the descriptors used to describe these technologies.

To begin with, the terms “autonomous” and “semi-autonomous” are frequently used to describe current systems which operate at extended distance and/or for extended times without constant control by a human operator. In the current era with artificial intelligence growing in use and application, the current use of those terms may be invalidated. Merriam-Webster defines autonomy as “existing or capable of existing independently.”⁷³ Even the most complicated weapons systems in the military do not have the ability to operate entirely independently, and therefore, are not autonomous. However, as artificial intelligence becomes more advanced, and particularly when it turns the corner from ANI to AGI/ASI, weapons systems may truly have the potential to be independent. Only then will weapons systems be autonomous. While in today’s environment there’s a common understanding of what ‘autonomy’ means, it’s important to keep the future in mind and begin modifying the lexicon in use appropriately.

Even the Department of Defense Instruction 3000.09, “Autonomy in Weapons Systems,” mentions “human-supervised autonomous weapons systems.”⁷⁴ That phrase itself is contradictory since a system cannot both be autonomous and supervised by humans. In the glossary of that document, an autonomous weapons system is defined as “A weapons system that, once activated [by a human operator], can select and engage targets without further intervention by a human operator... [T]his includes human-supervised autonomous weapons systems that are designed to allow human operators to override operation of the weapon system,

⁷³ <https://www.merriam-webster.com/dictionary/autonomous>.

⁷⁴ Department of Defense Directive (DODD) 3000.09, “Autonomy in Weapons Systems,” November 21, 2012, updated May 8, 2017, 3.

but can select and engage targets without further human input after activation.”⁷⁵ The inclusion of a requirement for human interaction with the system invalidates the very meaning of autonomy.

One example of how the lexicon might be improved is a reclassification of what are now called autonomous or semi-autonomous systems by different levels of control. The operation of Remotely Piloted Vehicles (RPVs), which are constantly controlled by a human operator from some distance, would be considered unmanned systems under Close Control (CC). Systems which check in with human operators at a set time periodicity would be under Periodic Control (PC), and if the systems check in upon facing a situation or event for which they are not programmed, they are under Situational Control (SC). This terminology, while simplistic, would be more accurate than calling these systems autonomous or semi-autonomous simply based on the length of time they are operating without direct human control.

Even the term “artificial intelligence” must be used with caution. At the U.S. Naval War College, there is a common discussion during the Joint Military Operations curriculum about the difference between the terms ‘complicated’ and ‘complex.’⁷⁶ A good example of a complicated system is a car engine; it has many parts, they are inter-related and dependent on each other, and the majority of operators have little to no idea how they operate. However, a car engine is not complex. An example of a complex system is a community of people. It can be relatively clearly defined, but there are many factors, predictable and not, that impact the members of the community. Another way of classifying these two examples is a relatively ‘closed’ system (although an engine still requires air and gas, admittedly) and an ‘open’ system.

⁷⁵ DODD 3000.09, 13-14.

⁷⁶ This description of the terms ‘complicated’ and ‘complex’ was taken from Joint Military Operations Department seminar discussions in which the author participated at the U.S. Naval War College in Fall, 2017.

There is a fine line between systems which operate based on complicated computer programming and algorithms, and those that demonstrate true artificial intelligence. Systems which follow the programming it has been given, however complicated, does not exhibit AI. Systems that can exhibit learning behaviors and interact with humans through means other than programming are using AI. Returning to an earlier example, this is why DeepBlue's defeat of Kasparov was not an example of AI (*complicated* computer programming), yet Watson's win on Jeopardy was (use of machine learning and natural language processing in a *complex* environment).

Control of Technology

Finally, there is much debate and discussion about the dangers of artificial intelligence. Elon Musk may be one of the most public people consistently expressing grave concern about AI. Specifically, the concerns center around how AI can be controlled, particularly when it reaches levels of human intelligence and truly begins to exercise the ability to learn independently of human-provided input and make its own decisions based on experience and external stimuli. This is pivotal when discussing military applications. When the matters being discussed involve life and death, the fog of war, and collateral damage, the ability for human operators to be involved in the process of engaging a target is of utmost importance. Considering the rapid pace of AI and its nearly ubiquitous presence globally, it's of grave concern that "[t]here are currently no multilateral standards or regulations covering military AI applications, and Member States have not systematically considered the challenges posed by AI technology through the UN or otherwise."⁷⁷

⁷⁷ https://www.itu.int/en/ITU-T/AI/Documents/Report/AI_for_Good_Global_Summit_Report_2017.pdf. 31.

Based on the current state of AI development, however, we still have a modest amount of time to correct this concern and incorporate the appropriate controls in AI before it reaches AGI and ASI levels of intelligence. Unfortunately, however, the very nature of those advances in AI may deem these ‘appropriate controls’ inadequate; this is what the author has called the “AI Control Paradox.” Unlike previous revolutionary advances in military technology such as the rifled barrel, radar, or even atomic weapons, AI is beyond an evolutionary advance, and even beyond a revolutionary advance. Computers with the ability to think on a human level (or beyond) and make decisions completely independent of programming will be autonomous in the fullest and most accurate way. That autonomy will allow those machines to work around, or simply ignore, the measures intended to control them and ensure they execute the will of their human operators. In fact, the paradox is similar when examining members of the military: while as humans we are autonomous, we follow orders such as rules of engagements – until we deem them unlawful, or otherwise find reason to disobey the guidance of our superiors. In summary, the “AI Control Paradox” says that by the time intelligent systems require a new means of being controlled, they will possess sufficient intelligence and autonomy to disobey those controls.

This is not a new challenge. In 1942, the well-known futurist Isaac Asimov first penned the “Three Laws of Robotics”:

1. A robot may not harm a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence, as long as such protection does not conflict with the First or Second Law.⁷⁸

⁷⁸ Lee McCauley, “AI Armageddon and the Three Laws of Robotics,” *Ethics and Information Technology* (2007) 9, 157.

While most of today's AI scientists are well familiar with the Three Laws, they also recognize that they were simply a literary product, and not a sincere answer to the technological challenge we face today. In a recent article, Oren Etzioni, the CEO of the Allen Institute for Artificial Intelligence, wrote that Brad Smith and Harry Shum had proposed new type of medical Hippocratic Oath for developers of AI-related technologies:

- I swear to fulfill, to the best of my ability and judgment, this covenant:
- I will respect the hard-won scientific gains of those scientists and engineers in whose steps I walk, and gladly share such knowledge as is mine with those who are to follow.
- I will apply, for the benefit of the humanity, all measures required, avoiding those twin traps of over-optimism and uniformed pessimism.
- I will remember that there is an art to AI as well as science, and that human concerns outweigh technological ones.
- Most especially must I tread with care in matters of life and death. If it is given me to save a life using AI, all thanks. But it may also be within AI's power to take a life; this awesome responsibility must be faced with great humbleness and awareness of my own frailty and the limitations of AI. Above all, I must not play at God nor let my technology do so.
- I will respect the privacy of humans for their personal data are not disclosed to AI systems so that the world may know.
- I will consider the impact of my work on fairness both in perpetuating historical biases, which is caused by the blind extrapolation from past data to future predictions, and in creating new conditions that increase economic or other inequality.
- My AI will prevent harm whenever it can, for prevention is preferable to cure.
- My AI will seek to collaborate with people for the greater good, rather than usurp the human role and supplant them.
- I will remember that I am not encountering dry data, mere zeros and ones, but human beings, whose interactions with my AI software may affect the person's freedom, family, or economic stability. My responsibility includes these related problems.
- I will remember that I remain a member of society, with special obligations to all my fellow human beings.⁷⁹

While noble, both the Three Laws and the proposed AI oath are naïve in that they preclude the possibility – or rather, the reality – that AI will be used for warfare. While

⁷⁹ Oren Etzioni, "A Hippocratic Oath for artificial intelligence practitioners," <https://techcrunch.com/2018/03/14/a-hippocratic-oath-for-artificial-intelligence-practitioners/>.

debates will always occur about whether war is just or unjust, that does not change the fact that war will occur, and countries will use whatever technology they can to prevail. As a result, some countries, or even non-state actors, will seek to incorporate these new technologies in their methods of fighting war, and have no moral or ethical constraints about the possibility of an autonomous system accepting collateral damage which a human operators – with rules of engagement and ethical considerations – might be unable to unwilling to accept. The question then becomes, how can the U.S. capitalize on these technologies and provide U.S. warfighters with every benefit our adversaries will undoubtedly possess, but still fulfill our moral obligations?

Recommendation for Tactical Control of AI

As previously explained, the very definition of deep learning includes the presence of ‘hidden layers’ in artificial neural networks. When AI makes decisions based on this deep learning, it is impossible to definitively explain why the AI made the decision it did; it did not use a simple decision tree which can be recreated in an ‘after-action report’ or ‘hotwash.’ One recommendation for how to provide the greatest capability, respect moral guidelines, and keep authority and responsibility for warfighting decisions at the tactical level (and not with the programmers or scientists who developed the AI) is to provide systems with dual-mode ANI/AGI processing.

During normal operations, operators at the tactical level would keep systems in ANI mode, using only artificial narrow intelligence. Decisions made by the systems would be explainable after tactical events but would draw real-time from a vastly greater number of sources and interact with the human operators in a way unrecognizable to today’s tactical operators. In the background, however, the AGI system would be

learning from the situations faced, adversary actions, patterns of behavior observed, weapons system performance, human actions in different circumstances, etc.

Additionally, the AGI would provide real-time warfighting options to the tactical operators. Those recommendations, due to the involvement of deep learning, might seem counter-intuitive to the operator; it would, therefore, be the decision of the operator to manually execute the AGI recommendation, go with the default ANI recommendation, or make their own decision.

On today's Aegis platforms in the U.S. Navy, a mode called 'Aegis Auto-Special' is available which removes the human operator from the firing sequence and execute engagements based on the kinetics of threats, including which weapons will be fired. In this proposed dual mode ANI/AGI system, a version of this option would also exist. In a dense threat environment, the human operator could switch the system to 'Full AGI' mode, at which time the human operator would be intentionally accepting the risk for whatever engagement decisions the AGI made – include those decisions unable to be explained, made in hidden layers of the neural networks. This recommendation may be a first step towards providing common-sense options for incorporating these technologies into the fleet at a speed of relevance.

Area for Further Research: AI Code of Conduct

In the nearer term, there needs to be a discussion about the creation and adoption of a 'Code of Conduct' or 'Maturity Model' for AI. While I was unable to explore this at depth during the course of my research, this is an area which could benefit from further research, to include a recommendation for an AI Maturity Model, or AIMM. Carnegie-Mellon University's Software Enterprise Institute (CMU SEI) had previously done a significant amount of work on

maturity models for the federal government. In fact, in 1986 SEI developed a framework intended to evaluate the maturity of organizations' processes of adopting software, specifically geared towards the federal government.⁸⁰ This branch of CMU has since split off as the Capability Maturity Model Institute (CMMI).

Certain aspects of CMMs, data maturity models (DMMs), and Technology Readiness Levels (TRLs) are all relevant to the discussion of artificial intelligence in several ways. First, the TRL is critical to evaluate how mature the AI technology is, which plays a pivotal role in whether or not the technology can be incorporated into warfighting systems during acquisition. TRLs range from TRL 1 to TRL 10. TRL 1 is defined as "basic principles observed and reported," and is the lowest level. This means the technology is still transitioning from the laboratory to possible applications. On the other end of the spectrum, Level 10 is defined as "actual system proven through successful mission operators," and is the most mature level.⁸¹ In my interview with Dr. Masakowski, she stressed both the need for a TRL assessment for AI evaluation, and also the need to accelerate the transition through these levels.⁸²

CMMs are used to quantify the maturity level of an organization's software process. It uses a series of five levels to describe the maturity level of the organization's software process: Initial (no process in place); Managed (basic controls in place); Defined (processes standardized across organization); Quantitatively Managed (quality of processes managed); and Optimizing (processes modified based on trending performance).⁸³ While TRLs are focused completely on

⁸⁰ "Capability Maturity Model for Software (Version 1.1)," <https://resources.sei.cmu.edu/library/asset-view.cfm?assetid=11955>.

⁸¹ "Technology Development: Technology Readiness Level (TRL)," <http://acqnotes.com/acqnote/tasks/technology-readiness-level>.

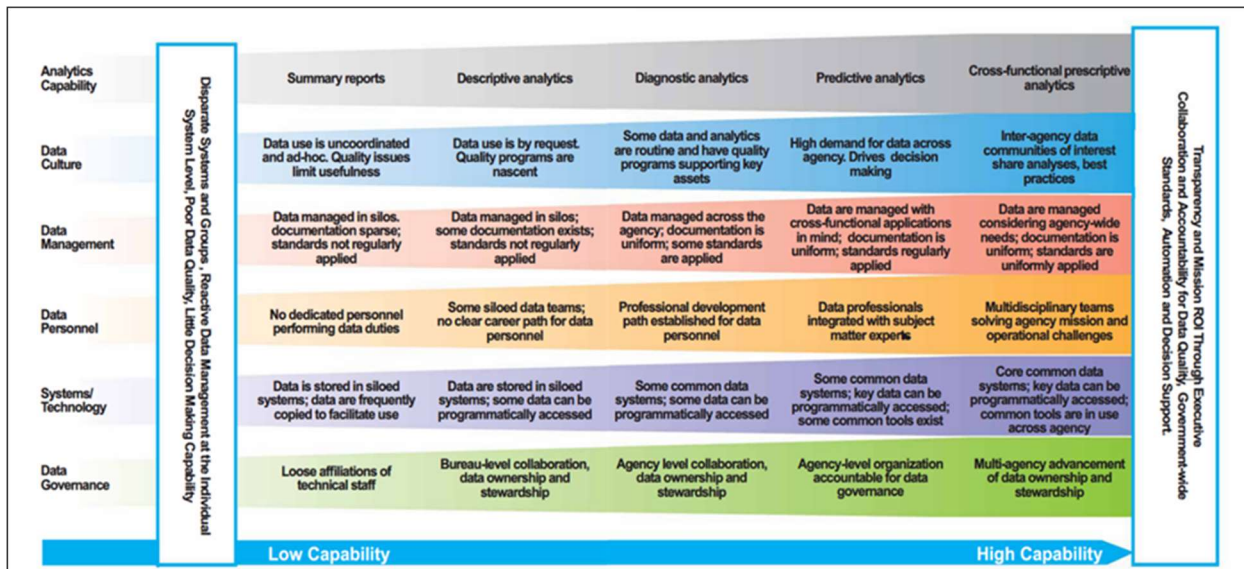
⁸² Masakowski.

⁸³ "What is Capability Maturity Model (CMM)? What are CMM Levels?," <http://istqbexamcertification.com/what-is-cmm-capability-maturity-model-what-are-cmm-levels/>.

the technology, CMMs are focused more on the organization itself, and the processes in place for incorporation and proper utilization and management of the technology.

Finally, DMMs focus on how data, or information, is being used and presented in organizations. One example is the Federal Government Data Maturity Model, from the Executive Office of the President of the United States. In that DMM, there are five levels of data maturity: Summary Reports; Descriptive Analytics; Diagnostic Analytics; Predictive Analytics; and Cross-functional Prescriptive Analytics.⁸⁴ In the diagram below, each of these levels has a corresponding description for five different facets of data: culture; management; personnel; systems/technology; and governance.

As you can see, each of these relate to some aspect of artificial intelligence, yet any one of them independently would be inadequate to guide the acquisition and intelligent incorporation



of AI into the federal government and the DoD. An AIMM would have to address each of these

⁸⁴ “The Federal Government Data Maturity Model,” Executive Office of the President of the United States, definitions and image retrieved from National Technical Information Service at www.ntis.gov/TheDataCabinet/assets/FDMM.pdf.

issues: the maturity of the technology readiness, the maturity of the organization to manage the technology, and the maturity of the data being used by the AI.

In light of the unique character of the technology in question, however, the challenge of creating an AIMM which addresses all these areas is not insignificant. In fact, Mr. Kruger stated as much by expressing reservations about how useful it will be to try to apply traditional ways of doing business to AI research. As he described, it's entirely possible to start a process with relatively mature AI technology, but then unexpectedly require less mature technology to proceed. To quote Mr. Kruger, "The DOD model that 6.1 [basic research] takes 10+ years, 6.2 [applied research] takes 5+ years does not work well in an environment where Stanford and Facebook research papers read alike."⁸⁵ However challenging the AIMM may be to create however, others agree that it is needed. In an e-mail with Dr. Yang Cai, the Senior Systems Scientist at CMU's CyLab, he stated "I think it's time to develop a new kind of CMM for AI with a new matrix of capacity measurements and training certifications."⁸⁶ The benefits of creating an AIMM and having it widely adopted are without question, but the development of that model must be a government/private industry cooperative effort and include the leading scientists in the field. Perhaps the new Select Committee on AI will recognize the need and utility for such a tool and dedicate themselves to its development.

⁸⁵ Mr. Martin Kruger (Office of Naval Research), e-mail message to author, March 27, 2018.

⁸⁶ Dr. Yang Cai (CMU Senior Systems Scientist), e-mail message to author, March 25, 2018.