Electronic Parts Manufacturing Industry Trends Impact on Conventional Ammunition Fuzes

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Date
7 April 2020

Published by
DAU

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ABSTRACT

Conventional ammunitions continue to provide safe, reliable, and operational effectiveness to the warfighter at an economical cost. Fuzes are a crucial element to all ammunitions but more critical to conventional ammunition. Fuzes for conventional ammunition differentiate by their fuzing technology forms: mechanical or electronic. This researcher analyzes the trend of the Electronic Parts Manufacturing Industry and evaluates the impact on the passive electronic components supply chain supporting the manufacturing of fuzes for conventional ammunition. As the delegated Single Manager for Conventional Ammunition (SMCA), the Joint Program Executive Office for Armaments and Ammunitions (JPEO A&A) is responsible for providing these capabilities to the US Army, US Marine Corps, US Air Force, and US Navy. This research also explores the challenges on the ability of the fuze industrial base to support future acquisitions and deliveries to maintain training and war reserve readiness.

Chapter 1 – Introduction

Background

According to reference DoD Directive 5160.65, the Secretary of Defense designated the Secretary of the Army as the DoD Single Manager for Conventional Ammunition (SMCA). The Secretary of the Army further delegated to the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA-AL&T), the authorities conferred by DoDD 5160.65. On 20 July 2010, the ASA(AL&T) appointed the now Joint Program Executive Office for Armaments and Ammunitions (JPEO A&A) as the Single Manager for Conventional Ammunition (SMCA).

As defined by DoD, a conventional ammunition is:

> "a*n end item, complete round, or materiel component charged with explosives, propellants, pyrotechnics, or initiating composition for use in connection with defense or offense (including demolitions) as well as ammunition used for training, ceremonial, or non-operational purposes. This includes inert devices that replicate live ammunition, commonly referred to as dummy ammunition, which contain no explosive materials."*

In addition to end items - such as small arms, mortar, tank, artillery, and gun ammunition - the conventional ammunition management responsibilities include components associated with those. Components include:

> "explosives, propellants, chemical agents, cartridges, propelling charges, projectiles, warheads (with various fillers such as high explosive, illuminating, incendiary, anti-

materiel, and anti-personnel), fuzes, boosters, and safe and arm devices in bulk, combination, or separately packaged items of issue for complete round assembly."

As part of the JPEO-A&A, the office of the Program Manager for Combat Ammunition (PM-CAS) is responsible, among others, for the acquisition of fuzes used on mortar and artillery ammunition. Mainly these fuzes comprise of mechanical (mostly used for training requirement), time (for illumination missions), and multi-option (for tactical use of smoke and high explosive ammunition). This research concentrates on time and multi-option fuzes that use electronic components.

A fuze is an armament subsystem that initiates the pre-established sequence of events that activates the warhead mechanisms. Conventional ammunition fuzes function in a binary state condition. They are required to remain inactive until the launch, and target conditions (ie impact, after impact delay, set-time, or target proximity) are met to then function within milliseconds. Fundamental to fuze functions are keeping the ammunition safe to handle and operate, arming, recognize or detect the target, and initiate the ammunition sequence of events resulting in cargo (smoke or illumination candle) expulsion or detonation of explosive for lethality.

Electronic time fuzes are used only in ammunition fired from rifled guns at a predetermined time set. The latest electronic time fuzes produced are the M762A1 and M767A1. They are nose-mounted fuzes used on 105mm and 155mm artillery-delivered cargo, smoke, and illumination projectiles. It can be hand set by rotating the ogive to provide a quick setting or by an inductive fuze setter. The M762A1 and M767A1 fuzes are an improvement over the M577/M582 series

mechanical time fuzes, by increasing rates of fire and reducing system response time. The M762A1 is used only with cargo carrying projectiles, while the M767A1 is used with high explosive fragmentation and bursting projectiles due to a booster assembly attached to its base end. The SMCA is also responsible for the acquisition of electronic fuzes for the US Air Force (FMU-160) and the US Navy (MK347 Multi-Option Fuze Navy - MOFN). For these, the SCMA doesn't manage the configuration management of the Technical Data Package (TDP).

Multi-option fuzes perform all fuze functions required on both conventional mortar (60mm, 81mm, and 120mm cartridges) and artillery (105mm and 155mm) artillery ammunition. They can provide four fuze function modes of timing, target impact (point detonating), after impact delay, and proximity (height of burst). The combined mode functions support a more comprehensive range of missions reducing the logistic burden as they replace seven legacy fuzes with a single fuze.

The M734A1 multi-option fuze is used on mortar ammunition (MOFM). It is set manually by rotating the ogive to the required function modes of point detonating, impact delay, or proximity height of burst. The M782 Multi-option fuzes for Artillery (MOFA) are set only by an inductive fuze setter. The M782 MOFA will resume production after an eleven year hiatus. Restarting production after a long period represents a challenge due to electronic components unavailability, obsolescence, or manufacturers' departure.

Production of mortar and artillery conventional ammunition fuzes requires the use of passive electronic components, semiconductors, integrated circuits (IC), and microprocessors. With the

rapid proliferation of cellular phones and their user applications, the extraordinary use of embedded sensors by the automobile industry, and the Internet of Things (IoT), passive electronic components availability are becoming scarcer. Cars are examples of the explosive application of sensors and electronic components used for monitoring all sorts of applications to include safety, fuel efficiency, and preventive maintenance (Figure 1). This situation is accentuated with the Department of Defense and the Department of Commerce regulations for qualified and authorized sources of semiconductors.

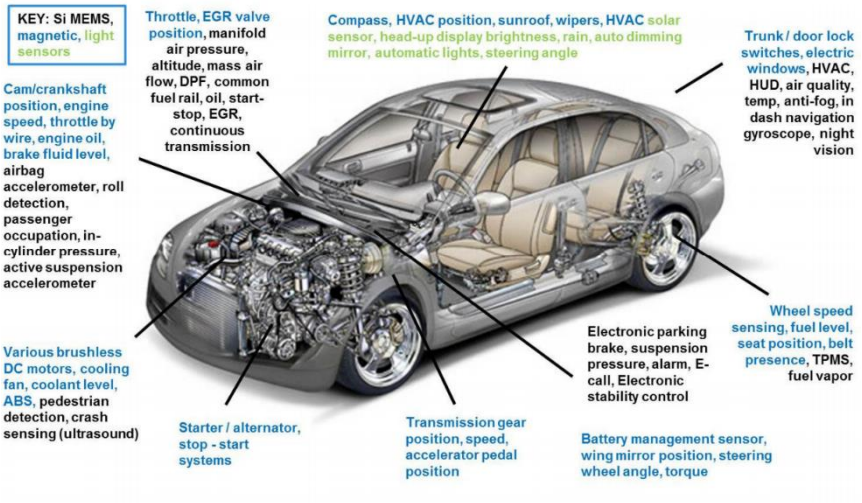

Figure 1 Is this an Automobile or a Computer on Wheels? (World Capital Partners, 2015)

For conventional ammunition fuzes, passive electronic components take the form of chip resistors and multi-layer ceramic capacitors (MLCC). Both components are produced in surface mount (SMT) configuration for rapid placement and soldering onto the surface of the printed circuit board. Production of SMT chip resistors and MLCCs has mostly replaced the through-hole technology construction method of fitting components with wire leads into holes in the circuit board.

World leader suppliers of passive electronic components include Murata Manufacturing, TDK Corporation, and Yageo Corporation. However, they don't play a role in the supply of these components for US ammunition production. Although relatively large players, Kemet Corporation, Vishay Intertechnology, and AVX don't have the influence as world-leading suppliers. Nevertheless, they can supply Commercial-Off-the-Shelve (COTS) electronic components that meet the mil-spec requirements of the fuze industry. All have been in business for over 55 years by organic growth or through mergers and acquisitions.

Spring 2017 marked the beginning of the electronic components shift from a buyer's to the seller's market. The availability of chip resistors and MLCCs have been diminished since then due to:

- "Electrification surge" has resulted in the sharp expansion of the cell phone, auto industry, and cloud-computing demands for electronic components in general.
- Japans/Korean semiconductor suppliers (Murata, TDK, and Yageo) exclude products for DoD ordnance production, including ammunition fuzes.
- Mergers and Acquisitions – Out of the top twenty significant semiconductor merger/acquisitions since 2001, eleven occurred in 2015-2016, resulting in a smaller pool of qualified suppliers.
- Supplier's reluctance to add capacity – Commercial-off-the-shelve (COTS) chip resistors and MLCCs components are considered "penny parts", typically running for about 25 cents representing a minuscule return-of-investment.
- Decreasing "case size" – SMT chip resistors and MLCCs come in a variety of sizes to fit the manufacturing pick and place machines and the specific location in the printed circuit

board. The growing trend is to shrink the case size, further reducing the components case size availability.

Problem Statement

The electronic parts manufacturing industry has been continuously assessed as mature and healthy. However, challenges in this industry and constant high demands required to support the cell phone and auto industries may impact the availability of electronic components to support the production of fuzes for mortars and artillery ammunition. This paper explores the combined multi-service upcoming fuze needs, according to the latest Program Objective Memorandum (POM) and Procurement P-Forms, compares them against the increasing demand of electronic components to support the cell phone, auto industries and the Internet of Things (IOT), and assess the potential challenges of the fuze industrial base on their ability to support the joint services need.

Purpose of This Study

The purpose of this study is to explore the interdependence of electronic components shared in the production of fuzes with the components used in the production of cell phones, auto industries, and the IOT. Also, to explore the impact on the ability of the fuze industrial base to support training and war reserve readiness. This research paper identifies the electronic components jointly used on mortar and electronic time and multi-option fuzes and the supply chain supporting the fuze manufacturing.

Significance of This Research

The significance of this research is that the findings and recommendations could be used to alert the Government and Industry of challenges and potential risks facing future fuze productions. These challenges and risks could also be used to develop courses of action to eliminate or mitigate them.

Overview of the Research Methodology

A qualitative review and evaluation of the current supply chain was performed in the area of acquisition of electronic components to support the mortars and artillery fuze production. Data was gathered from:

- Industry Organizations and Analysts: on the outlook of the semi-conductor industry
- Department of Defense Directives, Instructions, Plans, Reports and supporting Offices
- National Defense Industrial Association (NDIA) Industrial Committee of Ammunition Producers (ICAP): on current fuze manufacturers discussion about the challenges presented by the outlook of the semi-conductor industry
- Program Objective Memorandum (POM): on projected electronic components need to support the production of mortar and artillery fuzes.

Limitations

Most of the data and information is curtailed within a sector and infrequently shared with others. A significant limitation is the immediate scope that limits the research focus to passive electronic components: resistors and capacitors. There are other essential elements as semiconductors,

integrated circuits and microprocessors components, which also may be facing similar supply chain challenges.

Chapter 2 – Literature Review

The purpose of this literature review is to research the interdependence level of electronic components used in the production of conventional artillery and mortar ammunition fuzes with the components used in the production of cell phones and auto industries.

The questions this research paper explores are:

- Will the world electrification, emerging technologies (such as machine learning, Artificial Intelligence and the Internet of Things), and rapid development in the cell phone and automotive industries adversely affect the production of ammunition fuzes to support the delivery of conventional mortar and artillery ammunition?
- Can risks be assessed, and if so, corrective actions can be implemented to manage these risks?
- What other actions the office of the Program Manager for Combat Ammunition can develop to better secure the production?
- What other areas can be researched to assess the potential risks associated with the supply of passive electronic components supporting the production and delivery of conventional mortar and artillery ammunition?

The research reveals the followings:

- Directives and regulations establishing the responsibilities of the Joint Program Executive Office for Armaments and Ammunitions (JPEO A&A) as the Single Manager for Conventional Ammunition responsible for providing fuzes for artillery and mortars ammunition.
- Other efforts addressing the existing and forecast risks associated to the electronic component suppliers and the fuze industrial base.
- DoD offices with responsibilities associated with the problem addressed with this research.
- Industry efforts on assessing the risks associated with a potential shortage of electronic components supporting the fuze production for artillery and mortar ammunition.

For these research purposes the literature review is divided into three sections: US Government, Conventional Ammunition Fuze Industry, and Electronic Components Industry

US GOVERNMENT

Department of Defense Directive 5160.65 Single Manager for Conventional Ammunition (SMCA)

Recognizing that the US Army maintains most of the ammunition industrial base, in 1975, the Office of the Secretary of Defense (OSD) directed the creation of the Single Manager for Conventional Ammunition (SMCA). Included in this directive was the transfer of the Navy and Air Force ammunition industrial capabilities to the Army. Department of Defense Directive 5160.65 defines the SMCA responsibilities and structures to include the delegation of

acquisition, milestone decision, and contracting authority. The Secretary of the Army then delegated this authority to the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA-AL&T) as their primary function is to be the Army Acquisition Executive (AAE). On 20 July 2010, the ASA(AL&T) appointed the now Joint Program Executive Office for Armaments and Ammunitions (JPEO A&A) as the SMCA. JPEO-A&A "leads and manages the research, development, production, procurement" and delivery of lethal armaments and ammunition to the Joint Warfighter (Office of the Assistant Secretary of the Army (Acquisition, Logistics and Technolgies), 2018). It is "responsible for life-cycle acquisition management of conventional ammunition to provide the Joint Warfighter overmatch capabilities to defeat current and future threats." JPEO A&A consists of four Project Management (PM) offices: Project Manager Combat Ammunition Systems (PM-CAS), PM Close Combat Systems (PM-CCS), PM Maneuver Ammunition Systems (PM-MAS), PM Towed Artillery Systems (PM-TAS) and has two Project Director (PD) offices: PD Joint Services and PD Joint Bombs.

The Office of the PM-CAS is responsible for developing, producing, and equiping "Soldiers and Marines with conventional artillery and mortar ammunition, precision ammunition, mortar weapons, and mortar fire control systems" (Office of the Assistant Secretary of the Army (Acquisition, Logistics and Technolgies), 2018). Under the Single Manager for Conventional Ammunition (SMCA) responsibilities, PM CAS also procures ammunition for US Marine Corps, US Air Force, US Special Operations Command, and our allies. The PM-CAS is the life cycle program manager of artillery and mortar products.

Conventional Ammunition Line-of-Balance Forms

The Conventional Ammunition Division (CAD) of the office of the Program Manager for Combat Ammunition (PM-CAS) is responsible for the acquisition of fuzes used on mortar and artillery ammunition. As part of these acquisitions, CAD follows the status of the ammunition fuzes stockpile to fine-tune the overall acquisition process in support of the Training and War-Reserve Readiness Requirements. The Line-of-Balance Form tracks current units on inventory and production deliveries against Training, Testing, and War-Reserve needs. The results are used to trigger new acquisitions and balance the needs for new fuze deliveries.

M734A1 Multi-Option Fuze for Mortars (MOFM) and M782 Multi-Option Fuze Artillery (MOFA) Technical Data Package

PM-CAS is the Configuration Manager for all Artillery and Mortar ammunition. As Configuration Manager, PM-CAS manages the Artillery and Mortar conventional ammunition Technical Data Package (TDP) through "the process of establishing and maintaining the consistency of the performance, functional, and physical characteristics".

The TDP provides the technical "description of an item which is clear, complete and accurate, and in a form and format adequate for its intended use." DoD MIL-STD-31000B defines the TDPs as "the authoritative technical description of an item. This technical description supports the acquisition, production, inspection, engineering, and logistics support of the item. The description defines the required design configuration or performance requirements, and procedures required to ensure the adequacy of item performance. It consists of applicable technical data such as models, engineering design data, associated lists, specifications, standards,

performance requirements, quality assurance provisions, software documentation, and packaging details" (ARDEC, 2018).

Each conventional Artillery and Mortar ammunition fuze has its distinctive self-contained TDP (fuze TDP). The fuze TDP is used by contractors as produce to print and contains all required information for the load with explosive, assembly, and packaging for transportation and storage. The TDP, however, doesn't prescribe specific equipment, processes, and techniques for the production of the fuzes. The fuze TDP includes the specific subcomponents and components requirements, including the electronic components specifications and dimensions and tolerances. Every time a supplier deviates from the TDP, it requires government approval either through an Engineering Change Proposal (ECP) or Request for Deviation (RFD).

Procurement "P"-Forms (DAU Teaching Notes)

The Procurement Forms (or P-Forms) are one of the budget exhibits considered highly relevant documents supporting the preparation of the Defense portion of the President's Budget (PB). These exhibits represent the fund appropriation categories for Procurement (P-Forms); Research, Development, Test, and Evaluation (R-Forms); Operations and Maintenance (O-Forms); Military Personnel (M-Forms); and Military Construction (C-Forms)". They contain detailed justification for all resources requested in a clear, accurate, and consistent manner as analysts at the Service Headquarters, Office of the Secretary of Defense, Office of Management and Budget, and Congressional Staffers use these as the primary source of information about the programs.

The P-40 Form presents the Budget Item Justification summarizing the procurement planning, production schedule, and system cost. This investigation will focus on the P-40 Form for assessing the conventional ammunition fuze acquisition plans. Figure 2 illustrates the flow of program information into the Budget Item Justification Sheet P-40. The P-40 Form contains, among others, budget information about prior Fiscal Year (FY), current FY, the budget year (BY), plus four out-years (BY+1, BY+2, BY+3, and BY+4). A close review of the P-forms can provide the forecast of fuzes required for the next four years.

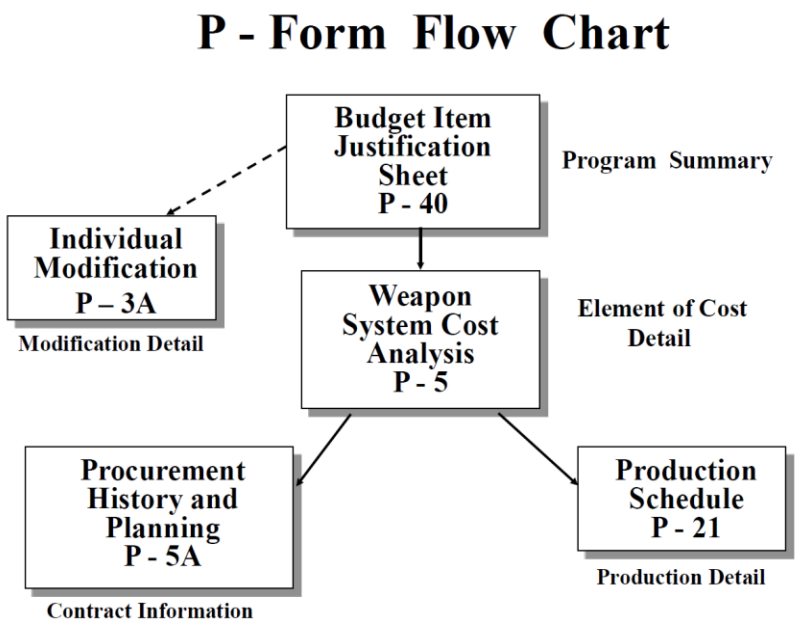

Figure 2 P-Forms Flow (DAU, 2011)

"National Defense University Industry Report (Electronics)" - The Dwight D. Eisenhower School for National Security and Resource Strategy

This study is the result of a five-month analysis of the semiconductor industry performed by fourteen (14) military and civilians representing the Secretary of Defense, US Army, US Navy,

US Air Force, Dept. of Energy, Air National Guard, and the Philippine and Saudi Arabia Army. The study provides an overview of the global semiconductor industry as part of the Electronic Industry Study Seminar conducted on January – May 2017 at the Dwight D. Eisenhower School for National Security and Resource Strategy. The analysis is the product of seminar instruction, industry, academy, and government office visits, and field studies both in the US and Asia. The study identifies strategic inflection point challenges and risks the global semiconductor industry faces. Challenges and risks are identified as they assess China's increasing competition, workforce, Visa program limitations, required government and private investments, and DoD and private security and integrity requirements. This effort also researches increased demands from the auto industry; global competition; and mergers, consolidations, and acquisitions within the semiconductor industry.

Industrial Policy's Assessments Directorate Office of the Deputy Assistant Secretary of Defense for Industrial Policy

The Industrial Policy Office is part of the Under Secretary of Defense for Acquisition and Sustainment. It provides "detailed analyses and in-depth understanding of the increasingly global, commercial, and financially complex industrial supply chain essential to our national defense." Two Directorates under the Industrial Policy Office focus resources on critical areas directly related to this research: Industrial Assessments and Industrial Base Analysis and Sustainment (IBAS).

The Industrial Assessments directorate "assesses the industrial base risks and identify mitigation strategies by integrating subject matter expertise, market analysis, and the principles of big data".

Results are included in the form of Industrial Policy (INDPOL) industrial base assessments addressing the "health and resiliency of the National Defense Industrial Base". INDPOL is responsible for the Annual Report to Congress: Industrial Capabilities. Some of the Industrial Assessments directorate capabilities of interest are the critical capabilities and fragility assessment of the supply chain, analysis of mergers and acquisitions transactions affecting the supply chain, and planning and implement risk mitigations.

The Industrial Base Analysis and Sustainment (IBAS) stipulates strategy goals to ensure that DoD "is positioned to more effectively and efficiently address industrial base issues and support the National Security Innovation Base." (Office of the Deputy Assistant Secretary of Defense, 2019) The "Annual Report to Congress: Industrial Capabilities" includes a section specifically addressing the potential investment prioritizations to "close gaps in defense manufacturing capabilities and create and sustain reliable sources" critical to readiness, among others.

Annual Report to Congress: Industrial Capabilities

This report is prepared by the Office of Industrial Policy (INDPOL) in the Office of the Secretary of Defense for the Committee on Armed Services of the Senate and the Committee on Armed Services of the House of Representatives. INDPOL's mission is to "ensure robust, secure, resilient, and innovative industrial capabilities upon which the Department of Defense (DoD) can rely to fulfill current and future warfighter requirements in an era of high power competition." (Office of the Deputy Assistant Secretary of Defense, 2019)

Starting with this May 2019 report, as stated by the reports requirement, “the annual industrial capabilities report will also provide Congress with updates related to the implementation and execution of the industrial base risk mitigation strategies and follow-on efforts related to Executive Order 13806 on Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States.” (Office of the Deputy Assistant Secretary of Defense, 2019)

The report covers a wide range of the National Defense Industrial Base (NDIB), including Munitions and Missiles, Electronics, Materials, and Workforce. The 2018 National Defense Strategy (NDS) emphasized the importance of the NDIB in “achieving a more lethal, resilient, and rapidly innovating Joint Force.” Appendix C of the report covers Key Industrial Capabilities Assessments and Initiatives during FY2018. After completing the assessments, DoD has already begun identifying the risks to the industrial base and implementing mitigation strategies. Specifically to this research, Appendix C includes an evaluation of the Multilayer Ceramic Capacitor (MLCC) Market.

Appendix D: “Title III, IBAS, and OSD ManTech Projects” covers the active Title III projects of the Defense Production Act; the status of the Industrial Base Analysis and Sustainment (IBAS) program; and current Manufacturing Technology (ManTech) applications to close manufacturing capabilities gap on the U.S. defense systems. Specifically related to this research, Appendix D also suggests potential prioritization efforts addressing the microelectronics industrial base and initiatives supporting the production of fuzes for missiles and munitions.

Platzer, et al, "U.S. Semiconductor Manufacturing: Industry Trends, Global Competition, Federal Policy"

Prepared by the Congressional Research Service (CRS) office, this report highlights the National Security concerns of maintaining a domestic advanced semiconductor manufacturing capability. Following the 2003 Deputy Secretary of Defense Paul Wolfowitz memorandum, DoD implemented a program of securing U.S. companies to guarantee "the access and reliability of components that are important to national defense." Since then, the U.S. has seen a contraction in the number of national microelectronics manufacturers requiring the House Armed Services Subcommittee on Oversight and Investigations to hold a hearing to assess the long-term viability of the DOD trusted supplier program. Future policy options include identifying new national foundries, alternative manufacturing approaches; or, establishing a government-owned fabrication facility.

Department of Defense Fuze Integration Product Team (DoD Fuze IPT)

On 6 December 2011 the Department of Defense (DoD) established the DoD Fuze Integrated Product Team (IPT) and associated Joint Fuze Technology Program (JFTP). Both are represented by the:

- Tri-Services (Air Force, Army and Navy) including US Marine Corp
- Office of the Secretary of Defense Acquisition, Technology and Logistics
- US Special Operations Command
- Department of Energy
- National Nuclear Security Administration Laboratories

In association with the service Project Executive Offices (PEOs), the DoD Fuze IPT / JFTP establishes and maintains a common list of fuze related technology gaps and addresses areas of potential failure that may affect the Fuze Industrial and Technology Base, the direction of Science and Technology (S&T) resources, and the overall War Fighter readiness. The DoD Fuze IPT / JFTP meets annually as part of the Technical Advisory Committee meeting. Their last meeting was in August 2019, covering four major fuze technology group/area accomplishments, Strategic and Munitions Applications, and a review of the S&T portfolio allocations for the Fiscal Year 2020.

The DoD Fuze IPT / JFTP manages Fuze Acquisition Information System (FAIS) to provide the PEOs an assessment into how their acquisition strategies impact the Fuze Industrial Base. The FAIS results are presented to the PEOs in the form of a "red flag" projection of risk assessment, DoD Fuze IPT analysis, and data showing the relative importance of each PEO's specific programs to each producer. Additionally, the PEOs can compare each producer's fuze capabilities and running "what-if" scenarios allowing adapting their acquisition strategies accordingly.

Defense MicroElectronics Activity (DMEA)

The Defense Microelectronics Activity (DMEA) reports to the Assistant Secretary of Defense for Research and Engineering and its mission is to provide microelectronic component and assembly solutions for the Department's legacy systems. As stated on their website, "DMEA works with the Department's Service organizations, Program Offices, and Depots to provide microelectronic components and assemblies for the Department's legacy systems." (DMEA, 2020) Then,

DMEA engages industry for preserving the required technological capabilities through the defense industrial base and commercial suppliers. Once a request is received, DMEA's "specialized microelectronic engineers" (DMEA, 2020) work with their staff and their industrial partner to assess the requirements and determine a set of possible solutions. Services range from just a device replacement solution to an entire system redesign. Fabrication of the solution is coordinated by DCMA either through industry or, as the last resolve, within their organic capabilities.

DoD Instruction 5200.44, Protection of Mission Critical Functions to Achieve Trusted Systems and Networks (TSN) requires that; "In applicable systems, integrated circuit-related products and services shall be procured from a trusted supplier accredited by the Defense Microelectronics Activity (DMEA) when they are custom-designed, custom-manufactured, or tailored for a specific DoD military end use (generally referred to as application-specific integrated circuits (ASICs))." (Takai & Kendall, 2017).

DMEA has the authority to accredit suppliers in the areas of "integrated circuit design, aggregation, broker, mask manufacturing, foundry, post-processing, packaging/assembly, and test services" (DMEA, 2020). These services cover a wide range of technologies and are intended to support both new and legacy applications, both classified and unclassified. Additionally, the use of the Trusted Suppliers' Trusted Flow is adequate to protect Critical Program Information as required by DODI 5200.39, Critical Program Information (CPI) Protection within the DoD (Lettre & Kendall, 2017).

Department of Commerce Defense Priority Authorization System (DPAS)

As defined by DAU, the Defense Priorities and Allocations System (DPAS) is used to "prioritize national defense related contracts/orders throughout the U.S. supply chain in order to support military, energy, homeland security, emergency preparedness, and critical infrastructure requirements."

Each mortar and artillery fuze contract includes a DPAS priority rating indicating "This is a rated order certified for national defense use, and you are required to follow all the provisions of the Defense Priorities and Allocations System regulation (15 CFR Part 700)". "All companies in the United States are required to accept and fill all rated orders for items that the company supplies typically" (CFR-2016-Title 15, 2016). This safeguards the U.S. Government against company discriminating against rated orders (rejecting, charging higher prices, or imposing different terms and conditions than for comparable unrated orders).

When competing for electronic components, contractors are required to prioritize deliveries of those components for over "not rated" orders such as those used on the automobile or cell phone industries.

A company may not accept a rated order on the ground of being unable to fulfill the order at the specific required date. In this case, the company may be fulfilling unrated or lower rate orders. However, previously accepted unrated or lower-rated orders is not ground for rejecting a rated order.

Combat Capabilities Development Command - Armaments Center (CCDC-AC)

Army Fuze Management Office (AFMO)

The Army Fuze Management Office (AFMO) is part of the Enterprise & Systems Integration Center within the Combat Capabilities Development Command - Armaments Center. AFMO is responsible for centralized management of the Army fuze and safety and arming (S&A) devices developed and fielded by the US Army for all non-nuclear munitions. Management and oversight responsibilities spread through the life cycle of those munition fuze programs and include maintaining "cognizance and participating in decisions during R&D, Production, Sustainment, De-Militarization, Pre-Planned Product Improvements (P3I), and Materiel Change (MC) programs."

The AFMO is the primary contact within the Army for Army-Navy-Air Force, fuzing standardization and policies. "The AFMO chairs as well as serves as the Army representative to national and international munition fuze committees such as NATO AC 326 SG/A and the DoD Fuze Engineering Standardization Working Group (FESWG). The AFMO assists, and chair as required, special study groups, special task forces, joint working groups, the DOD Fuze IPT, the Joint Fuze Technology Program, and acquisition teams on programs embodying fuzes."
The AFMO provides direct support, among others, to the Product Manager Offices under the Joint Program Executive Offices for Armaments and Ammunitions, fuzing related science and technology efforts, and the Army's munitions safety program.

CONVENTIONAL AMMUNTION FUZE INDUSTRY

Electronic Market Supply Chain Challenges

L3-Harris Technologies is one of the key producers of the Fuze Industrial Base. On 16 April 2018, they presented the Dwight D. Eisenhower School for National Security and Resource Strategy their electronic components supply chain challenges to support the current production of mortar.

L3 Harris presentation assesses the passive electronic components market and the impact on the supply chain of the world "electrification" surge and the automotive industry demand growth.

L3-Harris formed by the consolidation of the L3 Technologies and Harris Corporation carrying L3's expertise from the merger of L3 KDI Precision Products and L3 BT Fuze Products. They have developed and produced mechanical and electronic fuzing solutions including Safe & Arm Devices (S&As), and variable Height of Burst (HOBs) capabilities.

ELECTRONIC COMPONENTS INDUSTRY

The Internet of Things (IoT)

This report discusses this phenomenon and the spread to the "Things" with Sensors (energy, healthcare, transportation, defense, smart home, automobile, and wearables); Networking (gateways & routers, mobile networks); Communication Services (telecommunications/service provider network); Fast Data / Big Data Analytics; and Enterprise Applications. It also examines Mergers and Acquisitions as companies are positioning themselves to compete on the IoT scene.

Multi-Layer Chip Capacitor Market Update

The market updates are prepared by TTI Inc. through a letter to its customers. TTI is an authorized distributor of passive, connector, electromechanical, and discrete components. They offer market information to their customers, including articles, technical seminars, Restriction of Hazardous Substances on electronic components, and industry research reports, among others. On their 17 July 2019 update letter, TTI alerts industry of the Multi-Layer Chip Capacitor current capacity, future product roadmaps, and how these trends may be affecting the procurement of these components.

Resistors/Capacitors Lead Time Trends

The Resistors/Capacitors lead times are periodic assessments, also prepared by TTI Inc., of the current average manufacturer lead time for the products. In addition to production and delivery lead times, the evaluation includes time allocated for components requiring export licenses.

L3-Harris Technologies also performed a more in-depth analysis in April and November 2018 as part of their fuzing and ordnance contracts with DoD. Their analysis discussed the constraints from international suppliers, electronic components market allocations due to surge demands, significant mergers and acquisitions, and restrictions of USG Technical Data Package as challenges to support the production of electronic fuzes.

SEMI Association, "Semiconductor Mergers and Acquisitions Reach Peak"

Developments on this industry has a direct effect on the electronic parts manufacturing industry that produces passive electronic components. This article explores the mergers and acquisitions

affecting the semiconductor industry. Independently of the intent, mergers and acquisitions apply increased pressure on prices and availability of device makers, foundries, and fabless companies. As defined, “Fabless manufacturing is the design and sale of hardware devices and semiconductor chips and outsourcing their fabrication (or "fab") to a specialized manufacturer called a semiconductor foundry.” (Wikipedia, 2020)

Semiconductor Industry Association (SIA), “Global Semiconductor Sales in 2019”

The Semiconductor Industry Association (SIA) is a coalition formed in 1977 as a voice uniting the U.S. semiconductor industry and promote it as the key driver of the U.S. “economic strength, national security, and global competitiveness.” (Semiconductor Industry Association, 2020) SIA recognizes the U.S. semiconductor industry as one with 45% of the worldwide market share, with direct combined labor of approximately 250,000 employees, and the fourth U.S. largest export after airplane, refined and crude oil. The SIA coalition's primary purpose is to “strengthen the leadership of semiconductor manufacturing, design, and research by working with Congress, the Administration, and key industry stakeholders around the world to encourage policies that fuel innovation, propel business, and drive international competition.”

On 3 February 2020, SIA announces the global semiconductor industry sales. Sales are reported by semiconductor product segments and regions, including the total yearly revenues and Year-to-Year revenue percentage change since 1996.

Nathan Associates, "Beyond Borders: The Global Semiconductor Value Chain"

This report produced by the Semiconductor Industry Association describes the evolution of the semiconductor value chain, the benefits of the current economic system, and the risks of limiting the semiconductor value chain to a reduced number of countries.

Chapter 3 – Research Methodology

The research methodology supporting this paper stems from the fundamental supply and demand economic model as applied, however, to passive electronic components available to support the production and delivery of mortar and artillery fuzes for combat ammunition. If demand for semiconductor increases while supply remains unchanged, a shortage of semiconductors will occur. The increased demand ratio of semiconductors and electronic components supporting emerging technologies outpaces the demands for the production of fuzes supporting conventional mortar and artillery ammunitions. Also, semiconductors and electronic part manufacturers mergers and acquisitions, combined with the lack of the ability to tap into the biggest Asian manufacturers, reduce the supplier's pool available to support the conventional ammo fuze industrial base. The central question of this research then is:

- Will emerging technologies (such as artificial intelligence and the Internet of Things), and rapid development in the cell phone and automotive industries adversely affect the production of ammunition fuzes to support the delivery of conventional mortar and artillery ammunition?

Research Question

After contrasting the electronic component market conditions with current conventional ammunition fuze production and acquisition plans, the following subset of questions supports the research methodology.

- Can a risk assessment be performed and, if so, corrective actions be implemented to manage these risks?
- What other actions the Single Manager for Conventional Ammunition (SMCA) office can develop to better secure the production?
- What other areas can be researched to assess the potential risks associated with the supply of passive electronic components supporting the production and delivery of conventional mortar and artillery ammunition?

Research Design

This research steps into the Industry and Government office roles and responsibilities for supporting the manufacturing of electronic components used in the production of conventional mortar and artillery ammunition fuzes. Also, this research analyzes trends and forecasts on both the supply of electronic components and the acquisition/production of fuzes used on conventional ammunition. Following the literature review, the research is divided into the same three sections:

- The first section provides a summary of the function of the six Government offices connected to the central question of the research. This section intends to assess the

demand for passive electronic components and explore Government offices' existing involvement and interrelationship for effectively addressing the effect of the delivery of fuzes supporting conventional mortar and artillery ammunition.

- The second section reviews the view of the Conventional Ammunition Fuze Industrial Base for acquiring passive electronic components for the manufacturing of fuzes. This section intends to evaluate the Conventional Ammunition Fuze Industrial Base assessment on the availability of passive electronic components in the market to support manufacturing and on-time deliveries effectively.
- The third section reviews the periodic data analysis of the state of passive electronic component production. This intend is to evaluate the Electronic Parts Manufacturing Industry posture to supply passive components to the conventional ammunition fuze manufacturers effectively.

Bias and Error

Bias is defined as an "attitude of mind that predisposes one to favor something, or as in this case, preventing objective consideration of a question" ((n.d.)., 2020). There are various potential overarching sources of bias in the methodology:

1) the US Government ownership of the to-built Technical Data Package (TDP);
2) the adopted Horizontal Component Integration (HCI) acquisition strategy for the acquisition of fuzes for conventional mortar and artillery ammunition; and
3) electronic mortar and artillery fuzes have been produced by only two manufacturers for over 20 years.

Owning the TDP and HCI strategy may preclude considering alternate views of a particular problem or condition. Both of them bring the responsibility to the US Government that may constrain the flexibility that delivers a performance TDP on a System Contracting approach. Having only two manufacturers of conventional electronic fuzes may limit the motivation to move outside the TDP.

A potential source of error is the limited source of supply and demand data specific to the passive electronic components used on the fuzes currently in production. This data is crucial to gauge the level of risk being faced.

Chapter 4 – Findings

As stated in the research methodology, the fundamental research question stems from the application of the supply and demand economic model to passive electronic components supporting the production and delivery of mortar and artillery fuzes for combat ammunition.

Increased Competition for Electronic Components

Alothman et al. concluded that the global semiconductor industry, while currently assessed as mature and healthy, is facing a strategic inflection point. This inflection will shape a future for the industry that is significantly different than the past with "commercial semiconductor market shifts, unique DoD electronics needs, and ongoing requirements for rapid innovation" (Alothman, et al., 2017). Although their Electronic Industry Report was to shape Government

policy, they have asserted that DoD is a "mere blip in the sales numbers of major firms" of electronic components to dictate production runs (p.8, 2017). They also argued that the pace of the Defense Acquisition timelines is "incongruent with the rapid pace of the semiconductor industry" that, by the time of execution, required equipment and processes to support specific DoD acquisition might be phased out of the manufacturing process.

Fuze manufacturers reach to their brokers for approved electronic components. The approved electronic component suppliers are bound by DoD requirements/specifications, specific country laws that sometimes limit their components to non-ammunition applications, and by the market conditions restricting availability. Following the USG TDP, the order for electronic components needs to conform to the specific performance operational requirements and "case size" or physical dimension and tolerances.

A key industry partner in the production of mortar and artillery fuzes, L3-Harris Technologies (L-3) has raised concerns about the diminishing supply of passive electronic components supporting their manufacturing (L3-Harris Technologies, 2018). L-3 has been a supplier of fuzing technologies (L3 Harris, 2019) for armaments application since the acquisition of Gruen Watch Company military business unit to create KDI Precision Products in 1957. For over 30 years, they have been supplying electronic fuzes or fuze subsystems used on conventional mortar and artillery ammunition. In their discussions with the Dwight D. Eisenhower School for National Security and Resource Strategy (L3-Harris Technologies, 2018), L-3 points "commercial market forces driving the availability of parts" that results in diminishing the supply of passive electronic components. Significant to this research are:

- Japanese parts exclusion from US ammunition
- Consolidation of the supply source
- Obsolescence: Parts/ Electronic component obsolescence, and the rate of occurrence
- TDP changes to replace obsolete components

L3 makes references that important suppliers (such as Murata, Panasonic, Toshiba, and TDK) “will not support or sell” to certified electronic component brokers with direct ties to armament production, limiting competitive options thus reducing the supply while increasing lead-times and higher unit price. This restrain has been carried out by the Japanese Ministry of Foreign Affairs to include “(16) Equipment for the production or testing of arms, as well as parts and accessories thereof” in Japan’s Policies of the Control of Arms Exports - “The Government of Japan has been dealing carefully with "arms" exports per the Three Principles on Arms Exports (from now on referred to as "the Three Principles") and their related policy to avoid any possible aggravation of international conflicts” (Japan, 2020).

Another factor for the reduction of the supply of passive electronic components are Mergers and Acquisition (M&A). During 2001-2016 major consolidation transactions impacted the group of passive electronic component suppliers (Figure 3). M&A within approved manufacturers have resulted in “fewer sourcing options, and the Acquirer's reviewing part types for overall profitability and thus on onslaught of obsolescence is occurring as Manufacturer’s only want to continue to producing parts with the greatest demand” (L3-Harris Technologies, 2018).

Date	Acquiror	Target	Value
9/12/16	RENESAS	intersil	$2,961.9
7/26/16	ANALOG DEVICES	LINEAR TECHNOLOGY	13,267.3
7/18/16	SoftBank	ARM	30,164.7
6/14/16	JAC CAPITAL	NXP Standard Products Business	2,750.0
2/3/16	Micron	inotera	3,560.4
1/19/16	MICROCHIP	Atmel	3,278.4
11/24/15	Microsemi	PMC	2,293.0
11/18/15	ON	FAIRCHILD	2,222.9
6/1/15	intel	ALTERA	15,444.2
5/28/15	AVAGO TECHNOLOGIES	BROADCOM	33,688.7
3/2/15	NXP	freescale semiconductor	15,972.2
8/20/14	Infineon	IOR	2,261.9
6/9/14	ANALOG DEVICES	Hittite MICROWAVE CORPORATION	1,955.2
12/16/13	AVAGO TECHNOLOGIES	LSI	5,411.4
7/2/12	Micron	ELPIDA	2,520.0
6/22/12	MEDIATEK	Mstar	2,950.4
9/12/11	BROADCOM	NETLOGIC MICROSYSTEMS	3,448.8
4/4/11	TEXAS INSTRUMENTS	National Semiconductor	6,281.1
12/4/06	LSI	agere systems	3,539.1
7/24/06	AMD	ATI	5,106.8

Figure 3 Top 20 Semiconductor Transactions since 2001 (L3-Harris Technologies, 2018).

The national semiconductor industry M&As were a response of the global semiconductor arena market place. Global trends during 2008-2012 also showed a higher number of consolidation transactions in the industry. This period was characterized by a focus expansion of venture capitalists' shift on funding opportunities in software and the internet rather than hardware or semiconductors. This shift tightened venture funding into semiconductor companies leaving dominant semiconductor companies to acquire venture-backed companies with attractive sale channels, products, or Intellectual Property (Worldwide Capital Partners, 2016). Perhaps this

explains a consistent decline in the number of acquisitions (Figure 4) resulted in a sharp increase of the total transaction value of $117B in 2015 (higher than the previous seven years combined) (Worldwide Capital Partners, 2016).

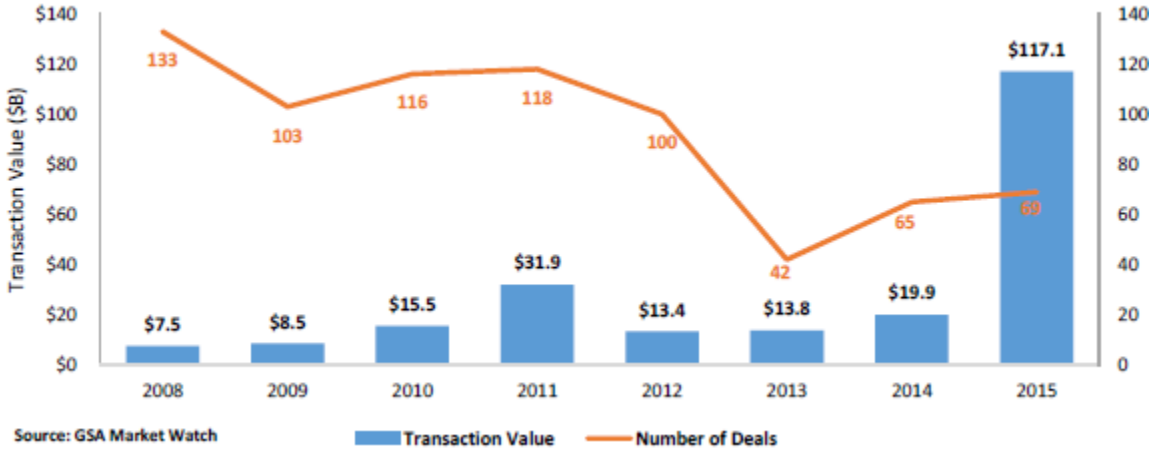

Figure 4 Semiconductor Consolidations (Worldwide Capital Partners, 2016)

The sales of semiconductors decreased both national and international. The Semiconductor Industry Association (SIA) announced 3 February 2020 a total 2019 sales decrease of "12.1 percent compared to the 2018 total." (Semiconductor Industry Association, 2020). Also, the Semiconductor Applications Forecaster from International Data Corporation (IDC) stated "an expected decline to $440 billion in 2019, down 7.2% from $474 billion in 2018." (International Data Corporation, 2019) This comes on after three consecutive years of sales growth, with an average 13.2% yearly leading to 2018. The semiconductor sales decline suggests that DoD will face less competition for semiconductors in the near future. However, the Internet of Things (IoT) may have the capacity to change this view.

As described by analysts, the IoT has the potential to grow the number of devices connected to the internet from 20.1 billion devices in 2020 to 41.6 billion devices connected by 2025 (International Data Corporation, 2019). This has the potential of an "economic impact of $2.7 trillion to $6.2 trillion annually by 2025" (World Capital Partners, 2015), attracting even more, the attention of the semiconductor industry. Such a dramatic surge is expected to increase the demands of electronic components considerably, and the amounts of M&As within manufacturers as companies "position themselves to compete on an IoT enabled landscape" (World Capital Partners, 2015). As the demand of electronics components increases the less motivation for the companies to keep their capital tight to manufacturing equipment and process for DoD products decreases (Platzer & Sargent, 2016) (Alothman, et al., 2017) (Office of the Deputy Assistant Secretary of Defense, 2019).

The inability to utilize Japanese suppliers, consolidation of suppliers and increased demand for electronic components has also increased the delivery lead-time schedule of passive electronic components. Specifically to this research, the lead-time for components has increased up to 16 weeks for capacitors, 44 weeks for resistors, and 54 weeks for diodes mainly used in the production of fuzes for conventional mortar production (Vitamia, 2018). Similarly, it can be expected those lead-times may be realized once production of conventional artillery electronic fuzes resumes from the year 2008 hiatus.

Independent market updates prepared for the national authorized distributor of passive, connector, electromechanical and discrete components also show this trend (TTI, Inc., 2018). TTI summarizes the causes to "dramatically increased in electronic content" (electrification

surge), “simultaneous demand increase across most market segments”, “suppliers’ reluctance to add capacity,” and supplier’s decision to cease production” (choosing to “exit some of the legacy” commodity products and shift that capacity to smaller, more economical case sizes”) (TTI, Inc., 2018). Also, the international suppliers market is on further competitive pressure as China continues to “grow its semiconductor capabilities and market share faster than the worldwide average, both through acquisition and through organic growth” (Worldwide Capital Partners, 2016).

Actions Taken by the US Government

- **Office of the Deputy Assistant Secretary of Defense for Industrial Policy - Industrial Policy’s Assessments Directorate:** The Industrial Base Analysis and Sustainment (IBAS) provides strategy goals to ensure DoD “is positioned to more effectively and efficiently address industrial base issues and support the National Security Innovation Base.” The “Annual Report to Congress: Industrial Capabilities” includes a section specifically addressing the potential investment prioritizations to “close gaps in defense manufacturing capabilities and create and sustain reliable sources” (Office of the Deputy Assistant Secretary of Defense, 2019) critical to readiness, among others. The report recognizes that “The most pressing tactical electronics issue consists of maintaining options for domestic trusted manufacture of custom DoD electronics and is the focus of the DoD Trusted Foundry Program, managed by the Defense Microelectronics Agency” (Office of the Deputy Assistant Secretary of Defense, 2019). Particularly to this research, they stated in Appendix D (“Title III, IBAS, and OSD ManTech Projects”), “The challenges facing the microelectronics industrial base are wide-reaching and significant. A DPA (Defense Production Act) Title III effort could prioritize production expansion to serve DoD’s need for

electronic materials; digital, analog, mixed signal integrated circuits; power electronic components, Electro-optical/IR components, radio frequency components, and other cross-cutting technologies." (Office of the Deputy Assistant Secretary of Defense, 2019) The Defense Production Act of 1950 authorizes the President "broad authority to ensure the timely availability of essential domestic industrial resources to support national defense" (Deputy Assistant Secretary of Defense, 2020).

Conclusions are similar to the reported by the industry that "most MLCC manufacturers are not increasing capacity, especially in the Asia-Pacific region. This is due to manufacturers converting production capacity reserved for general-type MLCCs into high-end capacitors used for the production of automobiles and smartphones. This caused the general MLCC shortage, and the price of these capacitors is going up as a result." Also, "prices of raw materials used in general MLCCs such as nickel, copper, and palladium have been climbing since the end of 2015, putting more pressure on MLCC manufacturers to keep costs down. Manufacturing high-end MLCCs is cost-effective in raw materials, space for storage, and a number of factors, making it an attractive alternative for producers." (Office of the Deputy Assistant Secretary of Defense, 2019)

Action reported by the Industrial Policy's Assessments Directorate is through the Defense Logistics Agency (DLA), which is "leveraging both commercial and government purchases of backlogged ceramic capacitors from third-party suppliers and valid DoD manufacturers to warehouse the ceramic capacitor. This is allowing DLA to retain some excess capacitors within its system to mitigate lead time issues." (Office of the Deputy Assistant Secretary of Defense, 2019)

- **Defense MicroElectronics Activity (DMEA):** DMEA reports to the Assistant Secretary of Defense for Research and Engineering with the "mission to provide microelectronic components and assembly solutions for the Department's legacy systems" (DMEA, 2020). In coordination with the Department's Service organizations, Program Offices, and Depots, they can supply microelectronic components and assemblies for the DoD legacy systems. Also, to accredit trusted electronic components suppliers (including design, broker, foundry, packaging/assembly, and test services), DMEA supports specific availability needs as part of their business model to particular needs (Figure 5). In the case of a Program Manager (PM) Office, DMEA engages both the PMs and their industrial partner to assess the requirements and determine possible solutions, including device replacement, reverse engineering, and system redesign. Once concurred by the PM office, DMEA issues a solicitation to industry for those components in need. "If industry does not respond, or cannot produce the part, DMEA serves as the source of last resort and fabricates the part at its facilities" (DMEA, 2020).

There are numerous success stories cited by DMEA as part of the "thousands of clients" (DMEA, 2020). Customers have included DoD, other US Government offices, commerce, and academia. The range of solutions achieved includes electronic components replacement, reverse engineering and redesign, technical support, modeling and simulation, and price and availability analysis.

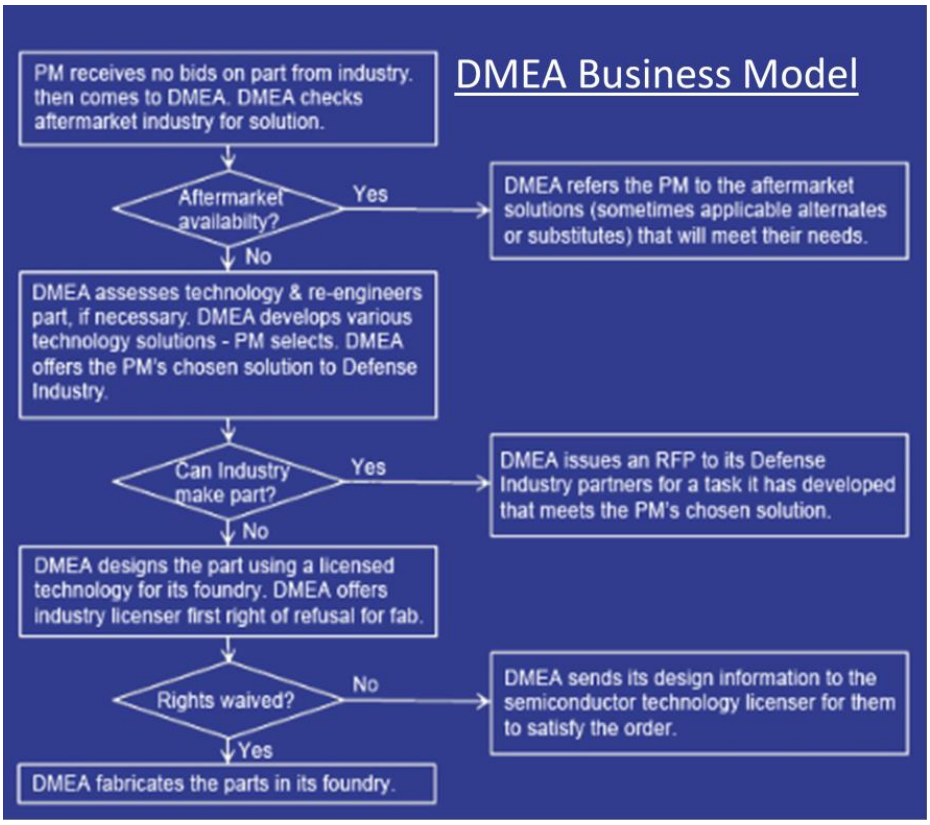

Figure 5 DMEA Business Model (DMEA, 2020)

- **Department of Commerce Defense Priority Authorization System (DPAS):** The Defense Priorities and Allocations System (DPAS) is used to "prioritize national defense related contracts/orders throughout the U.S. supply chain in order to support military, energy, homeland security, emergency preparedness, and critical infrastructure requirements" (DAU, unknown). As applicable to this research, the first page of a contract issued by the Army Contracting Command includes the program rated order program. Program rating identification abbreviations are included in Figure 6.

A1	Aircraft
A2	Missiles
A3	Ships
A4	Tank—Automotive
A5	Weapons
A6	Ammunition
A7	Electronic and communications equipment
B1	Military building supplies
B8	Production equipment (for defense contractor's account).
B9	Production equipment (Government owned)
C1	Food resources (combat rations)
C2	Department of Defense construction
C3	Maintenance, repair, and operating supplies (MRO) for Department of Defense facilities.
C9	Miscellaneous

Figure 6 DPAS Defense Approved Program (CFR-2016-Title 15, 2016)

Rated orders are either DX or DO followed by a program identification symbol. DX rated programs, and their orders are of the highest national defense urgency and are approved by the Secretary of Defense or Deputy Secretary of Defense. Conventional mortar and artillery fuze contracts include a DPAS DOA6 priority indicating an Approved Program supporting Ammunition.

The priority ratings and rated orders are contained in the Code of Federal Regulations (CFR) Title 15 - Commerce and Foreign Trade, Part 700 - DEFENSE PRIORITIES AND ALLOCATIONS SYSTEM, Subchapter A – National Security Industrial Base Regulations.

"§ 700.3 Priority ratings and rated orders.

(a) Rated orders are identified by a priority rating and a program identification symbol. Rated orders take precedence over all unrated orders as necessary to meet required delivery dates. Among rated orders, DX rated orders take precedence over DO rated orders. Program identification symbols indicate which approved program is attributed to the rated order.

(b) Persons receiving rated orders must give them preferential treatment as required by this part.

(c) All rated orders must be scheduled to the extent possible to ensure delivery by the required delivery date.

(d) Persons who receive rated orders must in turn place rated orders with their suppliers for the items they need to fill the orders. This provision ensures that suppliers will give priority treatment to rated orders from contractor to subcontractor to suppliers throughout the procurement chain.

(e) Persons may place a priority rating on orders only when they are in receipt of a rated order, have been explicitly authorized to do so by the Department of Commerce or a Delegate Agency, or are otherwise permitted to do so by this part." (CFR-2016-Title 15, 2016).

Sections 700.13 and 700.35 specifically discuss the "Acceptance and rejection of rated orders" under the Industrial Priorities Subpart and the "Mandatory acceptance of an allocation Order" under the Allocation Actions Subpart of the DPAS system. This could be interpreted that, when competing for electronic components, such as in the case to support the production of fuzes, contractors are required to prioritize deliveries of those components for over "not rated" orders such as those used, for example, on the automobile or cell phone industries. The rated order then can also be passed to their suppliers under the same stipulations. Section 700.74 provides the "safeguards" through penalties and remedies against "willful" violations against DPAS rated orders.

Important factors that may prevent the enforcement of the DPAS rating, and relevant to this research, are the followings:

- Electronic components "case size" specificity – Following on the literature research discussion of the Technical Data Package (TDP), conventional Artillery and Mortar ammunition fuzes have their distinctive self-inclusive TDP. They are used by contractors as produce-to-print requirements to implement their own equipment, process, and technological solutions for the production of the fuzes. The electronic component orders need to conform to the specific "case size" (physical component dimensioning and tolerances) to fit the automated pick-and-place assembly equipment unique to the contractor's operations. At the assembly process, the "case size" influences the mechanical interface between the electronic component and the pick-and-place equipment; and later on, the interface with the circuit board. A change in the "case size" will dictate changes on those mechanical interfaces that may enable an exception request.
- Loss of personnel, equipment, or processes – As manufacturers progress towards the production of smaller components "case size", equipment and processes are faced out while trained personnel relocates to respond to the times. By the time the fuze manufacturers reach the electronic component supplier, one of the critical pieces may not be in place for resuming production. At that time, the producer of electronic components may conclude the order is not cost-effective or just impossible to fulfill.
- Prolonged Interruption of USG Orders – Prolonged interruption of electronic fuze orders exacerbates the Government's position for companies to maintain the production of electronic components. As a clear case are the conventional artillery electronic fuzes, which were last produced in 2008.

- **Department of Defense Fuze Integration Product Team (DoD Fuze IPT):** The DoD Fuze IPT establishes and maintains a common list of fuze related technology gaps and addresses areas of potential failure that may affect the Fuze Industrial and Technology Base, the direction of Science and Technology (S&T) resources, and the overall War Fighter readiness. The DoD Fuze IPT, through the Fuze Acquisition Information System (FAIS), provides PEOs an assessment into how their acquisition strategies impact the Fuze Industrial Base. The FAIS results are presented in the form of a "red flag" risk assessment dashboard, DoD Fuze IPT analysis, and data showing the relative importance of each PEO's specific programs to each producer. With this information, PEOs can compare individual producer's fuze capabilities and running "what-if" scenarios (AT&L, 2011).

The DoD Fuze IPT manages four Fuze Area Technology Groups focusing on "developing, enabling, and common fuze technologies into DoD high priority weapon capability needs" mostly related to Science and Technology (S&T) 6.2 and 6.3 investments (Fan, Joint Fuze Technology Program, 2019). However, the nature of the IPT funding allocation doesn't reach to the specific challenge of supplying passive electronic components for the production of conventional mortar and artillery fuzes.

- **CCDC-AC Army Fuze Management Office (AFMO):** AFMO is responsible for centralized management of the Army fuze and safety and arming (S&A) devices developed and fielded by the US Army for all non-nuclear munitions. Management and oversight responsibilities include maintaining "cognizance and participating in decisions during R&D,

Production, Sustainment, De-Militarization, Pre-Planned Product Improvements (P3I), and Materiel Change (MC) programs." (CCDC-AC, 2013)

The AFMO is the primary contact within the Army for Army-Navy-Air Force, fuzing standardization and policies. "The AFMO chairs as well as serves as the Army representative to national and international munition fuze committees such as NATO AC 326 SG/A and the DoD Fuze Engineering Standardization Working Group (FESWG). The AFMO assists, and chair as required, special study groups, special task forces, joint working groups, the DOD Fuze IPT, the Joint Fuze Technology Program, and acquisition teams on programs embodying fuzes." (CCDC-AC, 2013). The AFMO also provides engineering support for the acquisition of electronic fuzes for the US Air Force (FMU-160) and the US Navy (MK347 Multi-Option Fuze Navy - MOFN).The AFMO provides direct support to the Product Manager Offices under the JPEO A&A, fuzing related science and technology efforts, and the Army's munitions safety program. Significant efforts coordinated with JPEO A&A and PM Offices are being driven through their Fuze Technology Initiatives (FTIs). In addition to modernization, FTI includes efforts on overcoming component's obsolescence and producibility risks and challenges.

- **Office of the Program Manager for Combat Ammunition Systems (PM-CAS):** PM-CAS continuously appraises the demands for Artillery and Mortars Conventional Ammunitions and assesses the risks on the supply chain. For this, they use current and projected Training and War-Reserve allocations, compares them against production deliveries, and ascertains fund planning allocations on the Defense portion of the President's Budget (PB). The projections are

that quantities for electronic mortar fuzes will decline through FY23 to then resume an increase through FY25.

As the SMCA for Conventional Artillery and Mortar Ammunitions, PM-CAS is also the Technical Data Package (TDP) Configuration Manager of these fuzes. PM-CAS is an active participant of the AFMO FTI working group and is managing, among others, the risks of long-lead passive components supporting the production of Fuzes on contracts. At the moment of this research, only mortar fuzes are being produced under a Firmed-Fixed Price (FFP) Contract with L-3 Harris. As such, the Army Contracting Command – New Jersey (ACC-NJ), L-3 Harris, and PM-CAS have agreed on increasing the value of the original contract to account and enable the acquisition of long-lead electronic passive components. However, negotiating the acquisition of long-lead components has ascertained more difficult under an FFP contract. Especially when prices and deliveries encompasses the electronic component broker(s) and the authorized electronic component manufacturer(s).

Chapter 5 – Interpretation

The research methodology supporting this paper derives from the fundamental supply and demand economic model as applied, however, to passive electronic components availability to support the production and delivery of mortar and artillery fuzes for combat ammunition. The increased demand ratio of electronic components supporting emerging technologies outpaces the demands for the production of fuzes supporting conventional mortar and artillery ammunitions.

This research explores the increased demand ratio of electronic components supporting emerging technologies outpacing the demands for the production of fuzes supporting conventional mortar and artillery ammunitions. It also explores the potential impact on the ability of the fuze industrial base to acquire the required passive electronic components to support training and war reserve readiness.

Conclusions

The conclusions from this research evolve from the main research question regarding the risk that the market conditions of passive electronic components poses on the production of fuzes for conventional mortar and artillery ammunitions.

Risk is defined as the probability of occurrence and consequence(s) of an event. The "DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs" establishes that "each risk should be evaluated in terms of impact to the program (i.e., effect of the event on program cost, schedule, and performance) should the risk be fully realized." (p.24). The findings from this research can support the argument that a risk has been realized and conditions have moved into an issue. "An issue differs from a risk in that its occurrence is certain, not probabilistic" (p.24) and may have occurred from a previously identified or unidentified risk (Department of Defense Risk, Issue, and Opportunity Management Guide for Defense Acquisiton Programs, 2017).

The main conclusion reached is that the existing semiconductor market conditions have resulted in an impractical availability of passive electronic components to support the production of fuzes

for conventional mortar and artillery ammunition. Increase in global competition for semiconductors resulted in exorbitant long-leads of passive electronic components. Contributing to this conclusion are the followings:

- Potential Semiconductor Industry Inflection Point – Despite a decline in global semiconductor sales in 2018-19, the forecasted demands of the Internet of Things (IoT) of 41.6 billion devices connected by 2025 may be propelling this industry to the inflection point argued on the 2017 National Defense University Electronic Industry Report (Alothman, et al., 2017). This inflection could assist the increase "commercial semiconductor market shifts, unique DoD electronics needs, and ongoing requirements for rapid innovation" (Alothman, et al., 2017). Also, the IoT may expect commercial market shifts to further fuel industry mergers and acquisitions as a response to the need to continue with rapid innovation. A semiconductor industry inflection point and further mergers and acquisitions will significantly impact the availability of passive electronic components.

- More Commercial Competition for Components means less DoD Acquisition Power – As asserted by Alothman et al., the Department of Defense (DoD) is a "mere blip in the sales numbers of major firms" of electronic components to dictate production runs (p.8, 2017)". The increased forecast in devices connections from the Internet of Things, accompanied by the semiconductor suppliers decline due to Mergers and Acquisitions, will further reduce the DoD acquisition power for passive components. Moreover, the passive electronic components "Case Size" specificity prescribed in the conventional mortar and artillery fuze Technical Data Package (TDP) further reduces the probability to entice attention from the semiconductor industry.

- Likely Production Equipment Phase-out and Personnel Relocation – It is not far fetching to expect that as the semiconductor industry keeps introducing electronic components with smaller "case-size", it will render replaced manufacturing equipment as uneconomical to maintain. During the equipment phase-out, companies may divest or sell it while manufacturing personnel is retrained or realigned to another production activity. When future DoD orders arrive, equipment and personnel availability may no longer exist to execute the production.

- Difficult to Establish an Enforcement Path on DPAS Rated Orders with Third Parties – The Defense Priority Authorization System (DPAS), Per 15 CFR Part 700, establishes that persons receiving orders are required to prioritize deliveries of "rated orders" over those without a rate. It also establishes penalties and remedies against deliberate violations against rated orders. However, contracts should be in place throughout the supply chain, passing the DPAS rated order to second or third-tier suppliers. Relevant to this research, is not until a funded order is executed through the Army Contract Command when the fuze manufacturer (DoD contractor) reaches to their brokers (second-tier supplier) for price and availability of the components. By the time the broker approaches the electronic component manufacturers (third party), it is not clear how to enforce a third party to accept a DPAS rated order. As discussed, it is reasonable for an electronic component manufacturer not to take an order (other than economical): loss of equipment and personnel; prolonged interruption of UDG orders; and the "case size" particularity of the component used in the production of the conventional ammunition fuze.

- Conventional Fuze Components Incongruence with Semiconductor Industry – Similar to Alothman et al. assertion that the pace of the Defense Acquisition timelines is "incongruent with the rapid pace of the semiconductor industry", the specificity of the electronic components used for the production of conventional ammunition fuzes is incongruent with the rapid "case size" change (miniaturization) by the semiconductor industry. This incongruence exacerbates timely apportionment of electronic components to support the conventional ammo fuze industrial base. Also, maintaining the electronic components "case-size" specificity limits the fuze manufacturer flexibility to propose an alternate component with the same functional electronic characteristics.

The last part of the main research question is related to the potential implementation of corrective actions to manage the main issue. Various offices within DoD have raised concerns, and they have begun efforts, about curtailing the shortages in the electronic industry. Funds appear to be appropriately allocated to focus DoD priorities, including the creation of the Defense Microelectronic Activity (DMEA) and the DoD Fuze Integration Product Team (DoD Fuze IPT). Also, resources have been allocated by CCDC-AC Fuze Management Office to address fuze component's obsolescence and producibility risks and challenges.

Recommendations

The research recommendations are based on the nature of the problem outlined in the conclusions and the last two research questions: what other actions can be taken, and what other areas can be researched (to assess the potential risk of diminishing availability of passive electronic components used in the production of fuzes for conventional ammunition).

Rather than moving to the apparent recommendation of forming a taskforce or red team to further research this specific topic, the research findings impacting the fuze industrial base needs to be verified and bound.

- Verify the Extent and Effectiveness of Government Office Mandates - In their report to Congress, the Office of the Deputy Assistant Secretary of Defense for Industrial Policy conveyed the capacity of the Defense Logistics Agency (DLA) to "stockpile" a specific passive electronic component. Once verified, it can be explored if this may also apply to other passive electronic components for the production of conventional mortar and artillery ammunition fuzes.

An additional step is to exercise the Defense Microelectronic Activity (DMEA) Business Model described in the Findings section. The moment the requirement needs have been assessed by DMEA, obtain the timeline for reaching industry and recommending the alternatives to the Program Manager Office of Combat Ammunition Systems.

Similarly, reach to the DPAS Subject Matter Expert at the Office of the Deputy Assistant Secretary of Defense for Industrial Policy before contacting the Department of Commerce regarding prioritizing deliveries of "rated orders" on approved semiconductor suppliers. This will require coordination with the Industry Partner with the Fuze contract.

- Expand the Research into Artillery Fuzes and Other Conventional Fuzes – Conventional electronic artillery fuzes managed by the Single Manager for Conventional Ammunitions have been out of production for over ten years. Although portions of the artillery fuze Technical Data

Packages have been updated, we can expect component obsolescence and loss of manufacturers/equipment to produce passive electronic components. Additionally, an assessment may be recommended to other conventional ammunition fuzes managed by the SMCA (tank ammo, grenades, etc.) or unique to the US Navy and US Air Force.

- Explore Flexibilize the TDP to Performance Specification – The literature review established that each conventional Artillery and Mortar ammunition fuze has its distinctive self-contained Technical Data Package (TDP). The fuze TDP is used by contractors as produce to print and contains all required information for the load with explosive, assembly, and packaging for transportation and storage. The TDP, however, doesn't prescribe specific equipment, processes, and techniques for the production of the fuzes. The fuze TDP includes the specific subcomponents and components requirements, including the electronic components specifications and dimensions and tolerances ("case-size").

Maintaining the electronic components "case-size" specificity limits the fuze manufacturer flexibility to propose an alternate solution while maintaining the same electronic characteristics. For the sub-system, where acquiring specific electronic component "case-size", it should consider moving the requirement from "build-to-print" to the performance specification of the sub-system. This has been proven during the acquisition of the FMU-160 fuze for the US Air Force. However, a straight forward substitution into performance specification has worked for the FMU-160 as quantities are far less and produced apart, making the acquisition of this fuze similar to a new development effort in order to prove conformance of technical and operational requirements.

Limitations of the Study

- Research Bias – Similar to the methodology, the three potential overarching sources of bias may have also limited the research scope and range. Having USG ownership of the Technical Data Package, Horizontal Component Integration (HCI) acquisition, and limited competition for the manufacturing of conventional fuzes may curtail the diverging thinking process when determining the range and depth, in this case, of the research (Puccio, Mance, & Murdock, 2011).

- Literature Research – Limiting the research to literature review constraints the depth and relevance of some of the information contained in reports, directives, and regulations. Areas that would have been explored were, for example, Defense Priority Authorization System (to verify rating enforcement on active component suppliers), Defense Microelectronic Activity (to discuss claimed successes applicability to this research), Defense Logistics Agency (to discuss the extent of their stockpile capabilities), and interviews with electronic components brokers and semiconductor industry representatives (to obtain their views, concerns, and plans related to the shortage of passive components and effectiveness of USG efforts).

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Glossary of Acronyms and Terms

AAE - Army Acquisition Executive

AFMO - Army Fuze Management Office

ASA-AL&T - Assistant Secretary of the Army for Acquisition, Logistics, and Technology

CCDC-AC - Combat Capabilities Development Command - Armaments Center

CAD - Conventional Ammunition Division

DAU - Defense Acquisition University

DCMA – Defense Contract Management Agency

DMEA - Defense Microelectronics Activity

DPAS - Defense Priorities and Allocations System

DoD - Department of Defense

ECP - Engineering Change Proposal

FY - Fiscal Year

IOT - Internet of Things

IBAS - Industrial Base Analysis and Sustainment

INDPOL - Industrial Policy

IPT - Integrated Product Team

JPEO A&A - Joint Program Executive Office for Armaments and Ammunitions

MLCC - Multilayer Ceramic Capacitor

MOFA - Multi-Option Fuze Artillery

OSD - Office of the Secretary of Defense

P-Forms - Procurement Forms

PM-CAS - Project Manager Combat Ammunition Systems

SMCA - Single Manager for Conventional Ammunition

TDP - Technical Data Package