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Industry Study

Final Report

Munitions



The Dwight D. Eisenhower School for National Security and Resource Strategy

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Munitions

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ABSTRACT

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Industry Study Outreach and Field Studies

The National Defense University, Eisenhower School Munitions Seminar engaged with numerous companies across the defense industrial base. Due to the circumstances surrounding the COVID-19 pandemic, most of these engagements were held by video teleconference.

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Mr. Dave Rogers and Mr. Bob Van Schaack, NAVSEA, Picatinny Arsenal, NJ

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Mr. Eirik Jensen and Mr. Scott Burk, Kongsberg Defence & Aerospace Inc., Alexandria, VA

Mr. Patrick Foster, American Rheinmetall Munitions Inc., Camden, AR

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Col Brad Tannehill, Joint Program Executive Office Armaments and Ammunition, Picatinny Arsenal, NJ

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Field Studies – Domestic

Pennsylvania State University Applied Research Lab, State College, PA

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Northrop Grumman Allegany Ballistics Laboratory (ABL), Rocket Center, WV

Aerojet Rocketdyne, Orange, VA

MELD Manufacturing, Christiansburg, VA

Holston Army Ammunition Plant, Kingsport, TN
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Commandant Lecture Series Addressing Mobilization and the Munitions Industry

Col Phil Zeman, USMC, National Defense University
Senator Marco Rubio, United States Senator, Florida
Mr. Eric Longnecker, Director Strategic Analysis Division, Strategic Industries & Economic Security, U.S. Department of Commerce
Ms. Katie Reid, Director within the Defense Production Act Program at the Federal Emergency Management Agency (FEMA)
Mr. Bill Soderberg, FBI Chair, National Defense University
Dr. Will Roper, Assistant Secretary of the Air Force for Acquisition, Technology and Logistics
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I. Introduction

For military members engaged in direct combat, access to a reliable and sufficient munitions supply is essential to lethality. As stated in a 2009 Lexington Institute study, “Maintaining an adequate supply of reliable ammunition is challenging under the best of circumstances. In wartime, the challenge becomes exponentially greater as demand increases, and pre-war production capabilities are stressed.”¹ Nineteen years of continuous combat, uncertain defense budgets, and a decline in critical suppliers have put great strains on the United States (U.S.) military resourcing systems and strategic stockpiles.² These strains have manifested themselves in aging equipment and infrastructure, shortages of low-density high demand assets, and concern over the ability to surge or mobilize for a high-end major theater war; the munitions industrial base (MIB) is no exception. Gaps in the MIB directly translate to gaps in the warfighter’s ability to deliver kinetic effects on targets. While portions of the MIB are vigorous and looking to expand market shares in rapidly changing technologies, the Department of Defense (DoD) and policymakers should undertake a coordinated effort to identify, mitigate, and retire current and projected risks in the MIB. The nation’s security and readiness for surge and/or mobilization in a great power conflict depends on a robust, secure, resilient, and innovative MIB.

The U.S. military continues to conduct limited combat operations around the world but must simultaneously ensure preparedness for large-scale operations. Timely munitions procurement to support current operations and to replenish strategic stockpiles mitigates risks. To highlight the strategic role that munitions play, the DoD fiscal year (FY) 2019 budget requested a 20% increase in munition procurement to support the President’s 2018 National Defense Strategy.³ (FY) 2021 requested budget highlights the strong role munitions will continue to play in strengthening the DoD and supporting the National Defense Strategy.⁴

Services FY2021 Requested Munitions Procurement Base Funding

Air Force: \$2.4Billion
 Army: \$7.1Billion
 Navy/Marine Corps: \$5.8Billion
 Total: \$15.3Billion

Source: Air Force, Army, and Navy Budget Overviews FY2021

Purpose

In Executive Order (EO) 13806, President Trump directed the Secretary of Defense to perform a thorough assessment of the defense industrial base (DIB).⁵ In compliance with EO 13806, an Interagency Task Force created an in-depth analysis titled, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*. The Task Force assessment identified significant issues and risks in the MIB. The purpose of this report is to further explore the health of the MIB to illuminate risks and propose recommendations that will ensure the strategic stability of the MIB in this era of great power competition.

Methodology

For this report, the Munitions Seminar analyzed the MIB as a market composed of unique products or services, producers, buyers, and rules that relate them. Research for this report was conducted over five months through site visits, teleconference meetings, thorough reviews of qualitative data, and interviews with MIB experts. Individual research efforts focused on the most prevalent areas of concern to identify causal relationships, links, and evidentiary arguments that can be translated into recommendations to strengthen the MIB. For this study, only conventional munitions and advanced/emerging technologies are discussed. The scope of this assessment was heavily biased towards the U.S. MIB and did not focus on acquisition strategies, individual service requirements, cyber threats to the MIB, or congressional involvement in the MIB. Due to their unique concerns, nuclear, biological, and chemical weapons were also outside the scope of this analysis. Finally, this paper referenced only open-source information to ensure the broadest distribution and to encourage further study.

II. MIB Key Terms and Definitions

Munitions

The DoD defines a munition as, “a complete device charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological, or chemical material for use in military operations, including demolitions.”⁶ Munitions, in their most basic form, are composed of two major components: 1) a warhead and 2) a propulsion system. Joint Publication 1-02, defines the warhead as, “that part of a missile, projectile, torpedo, rocket, or other munition which contains either the nuclear or thermonuclear system, high explosive system, chemical or biological agents, or inert materials intended to inflict damage.”⁷ The propulsion system is the portion of the munition system that is used to deliver the warhead to its intended target. In addition to the warhead and propulsion system, munitions can also be made up of numerous subcomponents such as fuze systems, guidance and flight control systems, electronic components and power supplies, and cases/bodies. Munitions can be thrown, dropped, projected, or placed.⁸ For this study, the focus is on this conventional DoD definition.

Energetics

To better define munitions, it is important to understand its key energetic components. Broadly, energetics consists of the explosive (the “boom”) and, in the case of a rocket, for instance, the propellant (the “whoosh”). These materials are composed of solids or liquids that contain a large amount of stored chemical energy.⁹ Both the warhead and propulsion systems depend on energetic materials to accomplish their role. Energetics determine the range, speed, terminal effect (lethality), safety characteristics, and signature for a munition.¹⁰

Based on their energetic content, munitions can be sensitive to heat, mechanical shock, and may be triggered by fire or impact with bullets/fragments. Secondary effects can cause significant damage and destruction.¹¹ The level of a munition’s sensitivity will determine if special packaging, handling, storage, and transportation (PHST) is required. Specially shielded and cushioned containers may be required for the PHST of certain munitions to reduce the risk of

sympathetic detonation of other munitions in case of an accident.¹² Due to their nature, energetics depend on a unique industrial base for their production, transportation, and storage.

To reduce risks associated with munitions, the MIB has made concerted efforts to develop increasingly insensitive munitions (IM). MIL-STD-2105 defines IM as, “munitions which reliably fulfill (specified) performance, readiness, and operational requirements on demand but which minimize the probability of inadvertent initiation and severity of subsequent collateral damage to the weapon platforms, logistic systems, and personnel when subjected to unplanned stimuli.”¹³ The increased safety associated with IM allows for less costly and more flexible PHST while lessening the hazard to the end-user warfighter. Over time, the DoD and MIB have moved away from using energetics such as trinitrotoluene (TNT) in munitions. Production has instead shifted to using safer IM such as Royal Demolition eXplosive (RDX), High Melting Explosive (HMX), and Composition B (a mixture of RDX and TNT).

Munitions Industrial Base

Given the unique considerations and hazards of munitions and their energetic content, an MIB has evolved to manage the full munitions enterprise, to include research and development. DoD Instruction (DoDI) 5000.60 defines the MIB as the public and private skills, knowledge, processes, facilities, materiel, and equipment needed to design, develop, manufacture, repair, and support DoD munitions products.¹⁴ The MIB is composed of a mix of contractor owned, contractor operated (COCO), government owned, contractor operated (GOCO), and government owned, government operated (GOGO) facilities. Both domestic and foreign companies are utilized in the MIB to meet America’s strategic munitions requirements.

Munitions Industrial Base Governance

Based on the complexity and expanse of the conventional MIB, the Office of the Secretary of Defense (OSD) has developed a system of governance to establish and maintain “a viable industrial base to sustain readiness.”¹⁵ As such, The DoD MIB is governed by a complex network of DoD and Service organizations that provide policy, guidance, and direction for the management of the MIB. At the macro level, the Deputy Assistant Secretary of Defense for Industrial Policy oversees the DIB. This office provides oversight of an Assessments Directorate that has purview of both the DIB and MIB. The Army is designated as the single manager for conventional munitions (SMCA). As the SMCA, their primary objective is to achieve the highest possible degree of effectiveness and efficiency to acquire conventional munitions and integrate logistic functions.

Munitions Supply Chain

Supply chain management (SCM) is a cradle-to-grave system that starts with the acquisition of raw materials through the final delivery of a product. The U.S. munitions industry relies on a global supply chain to effectively produce and deliver munitions to the warfighter. The munition supply chain is “dominated by sole- and single-source suppliers.”¹⁶ Unlike many traditional supply chains, MIB related supply chains do not, in many cases, function under predictable demand pulls. Requirements are generated from consumption estimates based on combat and

training intensities and can be inaccurate. Thus, production estimates are uncertain and risky for the commercial components of the MIB.

Surge and Mobilization

Much discussion of war includes the terms “surge” and “mobilization” with regards to the Defense Industrial Base. Whether the “war” is a conventional military conflict or a “war” against a world-wide pandemic, surge and mobilization of the Industrial Base are important. Surge refers to a supportable increase in the production of an item or system to 100% of capacity within 12 months to meet increased demand.¹⁷ For example, 3M shifted to surge capacity in manufacturing N95 respirator masks to support the increased demand due to the Australian wildfires, a volcano eruption in the Philippines, and the Coronavirus Disease 2019 (COVID-19) pandemic.¹⁸ Another example is the hockey equipment manufacturer, Bauer, who switched from producing hockey equipment such as face shields to manufacturing medical safety shields during the COVID-19 pandemic.¹⁹ Mobilization refers to a sustainable increase in the production of an item or system to 300% of capacity within 36 months.²⁰ During World War II (WWII), the U.S. mobilized industry to convert production from automobiles and appliances to provide equipment (tanks, trucks, ships, planes, munitions) for the military and its allies. Similarly, during the COVID-19 pandemic, the President enacted the Defense Production Act²¹, and companies such as Ford and GM are converting from automotive production to manufacturing medical equipment such as ventilators.²²

III. Primary Stakeholders in the MIB

As highlighted above, the MIB is a complex system composed of contractors, subcontractors, and facilities. Broadly, these break down to GOGO, GOCO, and COCO munitions plants. Key amongst these facilities are 17 organic Army ammunition plants, depots, arsenals, and activities. These 17 Army installations are organized as a mix of GOGO and GOCO facilities, and facilitate the complex program management and logistics of the contracting, production, maintenance, storage, and transport of components and munitions. In addition, a combination of government-owned, government-contracted, and contractor sponsored applied research laboratories conduct research and development (R&D) of new munitions systems/capabilities, improved production processes, and safer munitions. The success of the MIB depends on precisely choreographed processes and relationships to integrate the munitions components to create ready to use “all-up-rounds” (AUR) for warfighter use.

Government Owned, Government Operated (GOGO)

The government-owned portion of the MIB is essential to ensuring the ability to meet critical DoD munitions requirements. To maintain baseline competence, capacity, and technical knowledge within the MIB, the DoD maintains several GOGO munitions installations, maintaining capabilities to instruct private industry on how to manufacture munitions. Originally, these facilities served as the nucleus of production for wartime efforts, and, at their peak, over 60 GOGO operations existed in the U.S. to support WWII munitions requirements. To reduce accident and operational risk, most were built in rural areas.²³ A decrease in postwar munitions requirements and an

increase in privatization within the MIB led to closure or transition of many of these GOGO installations to GOCO or COCO operations. McAlester Army Ammunition Plant (AAP), OK and Letterkenny Army Depot, PA are examples of currently functioning GOGO facilities. In both cases, DoD workers produce munitions within the confines of limited Capitol Working Fund budgets, uncertain requirements, and competition from GOCO and COCO operations. Additionally, the Navy maintains two organic energetic entities (Naval Air Warfare Center Weapons Division China Lake, CA and Naval Surface Warfare Center Indian Head, MD) to augment the commercial base. The Navy also operates four weapons stations that store, refurbish and issue munitions to Navy ships, subs, and aircraft. (For a list of organic DoD Munitions facilities, see Appendix A). Historic underfunding of GOGO facilities (estimated at over 20% poor or failed conditions) have led to renewed efforts toward modernization and, in some cases, privatization.²⁴

Government Owned, Contractor Operated (GOCO)

The government also owns facilities operated by private contractors to produce, distribute, demilitarize, and store munitions and their components. GOCOs are the most utilized construct within the MIB today. As the two primary GOCO facilities in operation, Holston Army AAP, TN and Radford AAP, VA are critical to the MIB. Approximately 97% of DoD munitions contain a product produced at either facility.²⁵

<u>Holston AAP</u>	<u>Radford AAP</u>
<ul style="list-style-type: none"> ☛ Only U.S. producer of RDX and HMX—used in munitions for all DoD branches ☛ Constructed in 1942 ☛ GOCO facility ran by BAE Systems ☛ Explosive production and research for DoD and industry ☛ Key supplier of explosives to allies 	<ul style="list-style-type: none"> ☛ Produces constituent used in virtually every munition produced in U.S. MIB ☛ Constructed in 1940 ☛ GOCO facility ran by BAE Systems ☛ Propellant production for DoD and industry ☛ One-of-a-kind facility to produce nitrocellulose—North America’s only producer

Contractor Owned, Contractor Operated (COCO)

COCO facilities play a key role in ensuring military munitions requirements are met in peacetime and wartime. Historically, 70-75% of DoD munitions procurement has come from COCO facilities.²⁶ The DoD relies on COCO facilities to perform diverse missions in the MIB including design and engineering; development and manufacturing; analysis and inspection; and final load, assembly, and packing (LAP). BAE Systems, Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, and Raytheon all operate COCO facilities as part of the MIB.

The MIB supply chain is unique to the MIB in that COCO producers must rely on the government’s ability to provide propellant and explosives from GOCO facilities. Two examples of COCOs are Northrop Grumman’s Allegany Ballistics Laboratory in Rocket Center, WV, and American

Rheinmetall, located in East Camden AR. American Rheinmetall demonstrates what is possible at a COCO facility leveraging its Cold War-era U.S. Navy munitions storage bunkers and its relative freedom to improve its facilities footprint. According to Mr. Pat Foster, Director of Operations, assembly and storage of 40mm munitions occur within existing storage areas creating both a hardened and dispersed effect for munitions production. As a COCO, Rheinmetall has considerably more flexibility in upgrading and resetting these structures and provides an example of what is possible given the right mix of existing infrastructure, necessity, and private initiative.²⁷

Foreign Suppliers

In addition to domestic COCO operations, foreign suppliers from many allied and partner countries play a key role in contributing to the MIB. Foreign suppliers, such as Nammo, Saab, and Kongsberg Defence & Aerospace, provide both AURs as well as components used for manufacturing munitions. Allies such as Norway have managed to carve out a portion of the international defense industry in producing niche munitions. The U.S. currently procures munitions such as the Naval Strike Missile from Norway. Many of these munitions are too specialized for large U.S. prime defense contractors to produce cost-effectively. The foreign dimension adds complexity and a degree of vulnerability to the U.S. MIB. Dependency on the health of foreign economies and geopolitical relationships with the U.S. must be considered in any assessment of the viability and resiliency of the munitions supply chain (see Section VII, Essay 1).

Joint Munitions and Lethality Life Cycle Management Command (JM&L LCMC)

The Joint Munitions and Lethality Life Cycle Management Command (JM&L LCMC) was created to formalize the Army's munitions management to "supply warfighters faster, improve products, and minimize life-cycle costs."²⁸ The JM&L LCMC aligns several munitions stakeholders: the Joint Munitions Command (JMC), Joint Program Executive Office Armaments & Ammunition (JPEO A&A), and the U.S. Army Combat Capabilities Development Command Armaments Center. The JM&L LCMC mission is to "Develop, acquire, field, and sustain value-added ammunition for the joint warfighter through the integration of effective and timely acquisition, logistics, and cutting-edge technology".²⁹ The JM&L LCMC is co-located at Picatinny Arsenal, NJ, and Rock Island Arsenal, IL.

Joint Munitions Command (JMC)

JMC, located at Rock Island Arsenal, IL, has the mission to provide the armed forces with ready, reliable, lethal munitions to sustain global readiness. According to their website, "JMC provides the conventional ammunition life-cycle functions of logistics sustainment, readiness and acquisition support for all U.S. military services, other government agencies, and allied nations as directed. JMC is the logistics integrator for life-cycle management of ammunition providing a global presence of technical support to frontline units."³⁰ Organizationally, JMC falls under the U.S. Army Materiel Command, and it has oversight and control of the GOGO/GOCO plants and depots that distribute, store, demilitarize, and produce munitions.

Joint Program Executive Office Armaments & Ammunition (JPEO A&A)

JPEO A&A is one of the Program Executive Offices under the Army's Assistant Secretary for Acquisition, Logistics, and Technology (ASALT). JPEO A&A is responsible for life-cycle acquisition management of all conventional munitions, which includes integrating budgets, acquisition strategies, R&D, and life-cycle management across all munition families. JPEO A&A serves as the SMCA Executor and Field Operating Activity for the DoD.³¹

IV. Current Condition of the MIB Enterprise

Current Competitive Structure:

The current competitive structure in the MIB varies based on the product type. Much of the MIB is unique to the defense market and has no commercial or dual-use market. Due to the MIB's role in providing national defense and strategic deterrence and a lack of substitute systems, the demand for munitions is fairly inelastic. According to Harvard Business School Professors, Kenneth Cortis and Jan Rivkin, when demand is inelastic, the consumer will buy nearly the same amount if the price rises or falls.³² The number of sellers is also extremely limited in the MIB. Security clearance requirements, technical expertise, and experience in executing extremely high-dollar contracts with the U.S. government limit the potential suppliers to primarily top prime defense contractors. As a result, the supply is also inelastic and therefore relatively unresponsive to a change in demand.

70-75% of U.S. government munitions funding is contracted with COCOs.³³ Some munitions production has been contracted to multiple suppliers, but many MIB products are sole source items produced by one of six prime contractors (also known as Primes): BAE Systems, Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, and Raytheon. Primes often depend on an eclectic mix of small niche sub-tier suppliers for system components. At the same time, the prime contractors often contract the GOGOs and GOCOs for energetic materials and load, assembly, and pack operations. Finally, since the sector is primarily defense-unique and subject to fluctuating wartime needs, it creates significant viability challenges for suppliers and their sub-tiers.³⁴

Solid rocket motor production is an example of the multifaceted nature of the MIB industry. There are currently two domestic producers that supply solid rocket motors for most of the DoD's missile systems—Northrop Grumman Innovation Systems and Aerojet Rocketdyne. Northrop Grumman Innovation Systems, formally Orbital ATK, was acquired in 2018 to support Northrop's growing MIB market share and to try to leverage in-house efficiencies. These companies have transformed the solid rocket market into an oligopoly where only a very small number of firms compete and there are significant barriers to entry for new manufacturers.

Firm Viability

The health of MIB firms also differs. Although GOGOs, GOCOs, and COCOs conduct varying levels of business with foreign and domestic commercial and military customers, they depend heavily on the U.S. government as their largest single customer. Many MIB suppliers are monopsonies,

in that they depend on U.S. government contracts for survival. Some small sub-tier and niche suppliers are at greater risk due to uncertain funding and demand (discussed in Section V below). The six prime contractors mentioned above are for the most part healthy. This study assesses that they rely on four factors to continue their success: (1) constant demand for munitions due to years of conflict; (2) growing DoD budgets that focus on preparation for high-end conflict; (3) efficiencies gained by mergers and acquisitions; and (4) a strong ability to navigate the defense acquisition system and associated government bureaucracy. In 2018 and 2019, all six primes saw solid net profit margins within their munitions portfolio. Boeing's profit loss was largely due to troubles with its commercial aircraft manufacturing segment. Appendix B contains a financial breakdown of the six prime defense contractors mentioned above.

Role of Firms' Business Units

Multiple business units in the major prime contractors play a significant role in the MIB. Each company is diversified and produces varying commodities used in the manufacture of AURs. Also, prime contractors have a history of acquiring smaller or startup companies to leverage their technologies and reduce competition. Figure 1 highlights the multiple commodity categories in which MIB firm's business units manufacture.

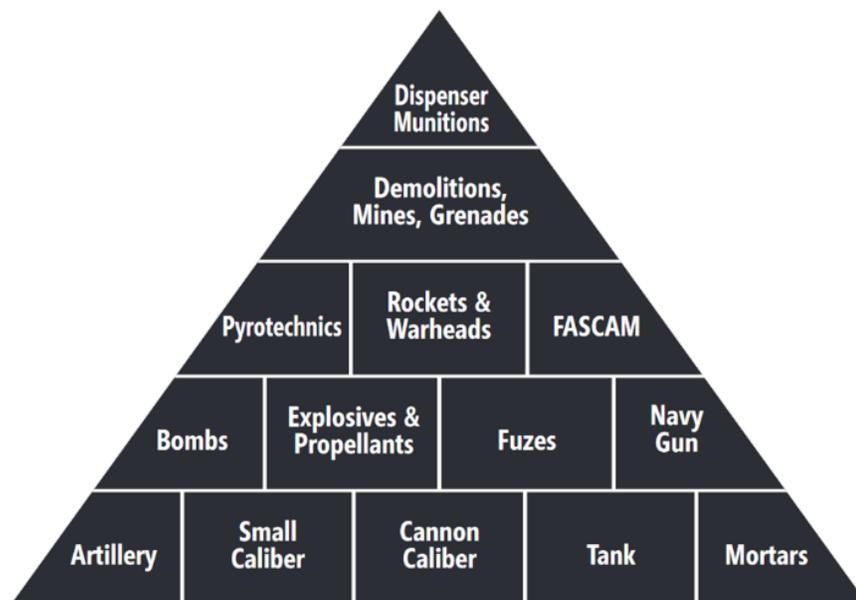


Figure 1: Munitions Family Commodity Categories

Source: Army Acquisition, Logistics & Technology, July-August 2004

Effective Business Strategies

Like most segments of the defense industry, the prominent business strategy for the prime contractors in the MIB is specialization and consolidation. As mentioned above, each defense prime is on contract to produce munitions of varying types. Many of the munitions are unique and have no viable substitute. In addition, prime contractors have a history of acquiring and consolidating smaller competitors. The downside to this business strategy is that less competition can drive up costs and reduce innovation. The latest example of this is the ongoing merger of Raytheon and United Technologies Corp. Raytheon manufactures the Tomahawk

Cruise Missile and United Technologies Corp produces key components for the Minuteman III missile system.³⁵ With this merger, the newly formed Raytheon Technologies Corporation now owns a sizeable portion of the missile production sector.

The business strategy of GOGO facilities primarily centers on the Army Working Capital Fund (AWCF). The AWCF is a revolving account that relies on sales revenue to finance its operations. AWCF facilities do not receive Congressional appropriations. All costs of operations are covered by rates and prices charged to customers.³⁶ There are no fiscal year limitations or further Congressional involvement as with appropriated funds. By design, AWCF facilities, such as Letterkenny Munitions Center, PA cannot make a profit. Prices for goods produced fluctuate to make up for profits or losses.³⁷ The Navy's two GOGO facilities are different, in that they receive both Navy Working Capital Funding (NWCF) and Research and Development Testing and Evaluation, Navy funding for their efforts.³⁸

V. Analysis of MIB Challenges

Infrastructure

During on-site visits, the team observed that many of the MIB GOCO and GOGO facilities were in poor condition with aging equipment. This was in line with the 2019 Government Accountability Office (GAO) report of Military Depots. The antiquated WWII construction, and years of deferred maintenance have taken a heavy toll on their condition. This deferred maintenance was driven by low DoD prioritization which resulted in a limited allocation of military construction (MILCON) and sustainment, reconstruction, and modernization funds. Addressing poor conditions will cost billions and require many years of sustained attention.³⁹ Because COCOs operate for profit, and are not restricted under working capital fund regulations, they are able to reinvest in infrastructure. As a result, their facilities are generally better maintained than GOGOs. While most COCO and GOCO facilities retain greater capability than their government-owned counterparts, the government must further invest to support surge and mobilization operations.

Recognizing the decline in government facility conditions, in the 2007 *National Defense Authorization Act* Congress enacted a policy requiring the services invest in the capital budgets of its depots. This policy requires an investment of no less than 6 percent of the average total dollar value of the combined maintenance, repair, and overhaul workload funded at all the depots of that department over the preceding three fiscal years.⁴⁰ Despite the dilapidated condition of munitions facilities, Army Materiel Command (AMC) assesses the undisrupted state of the MIB as low to medium risk (see Appendix C).⁴¹ Although AMC rates the overall readiness risk as low, JMC is concerned with the aging and vulnerable state of DoD munitions related facilities.⁴²

Given the strategic importance of Radford AAP, VA, and Holston AAP, TN, the DoD has begun an effort to invest in modernizing and repairing portions of their production lines. Both Radford AAP and Holston AAP have numerous modernization efforts underway. In 2016, Holston AAP completed a \$146M acetic acid/anhydride production facility to support RDX/HMX explosive

production. This new facility eliminated the need to transport acids over 7 miles from various buildings across the plant facility. Additionally, Radford AAP recently underwent a \$52M refurbishment effort to construct a new natural gas package boiler facility to replace a non-Environmental Protection Agency compliant 1940's coal plant.⁴³ Finally, Radford AAP currently has a \$240M project underway to replace its WWII-era nitrocellulose facility with a state of the art production plant.⁴⁴ The completion of the new facility is expected in 2021.

Demilitarization

Another important aspect of the MIB is the ability to demilitarize aging and obsolete munitions. DoD Manual 4160.28, Volume 1, *Defense Demilitarization: Program Administration* defines demilitarization as, "The act of eliminating the functional capabilities and inherent military design features from DoD personal property that requires certification and verification. Methods and degree range from removal and destruction of critical features to destruction by cutting, crushing, shredding, melting, burning, etc."⁴⁵ As of April 2019, JMC estimated there were over 346,000 short tons of munitions waiting for demilitarization. That amount makes up over 24% of the DoD total munitions footprint. The large inventory of munitions awaiting demilitarization places an extreme strain on readiness resources, infrastructure, and results in fragmented distribution operations. In addition, there is an extreme safety risk associated with degrading munitions in storage. To fix the problem, JMC has instituted a logistics strategy reform to significantly reduce the excess munitions footprint by the end of 2025.⁴⁶

MIB Enterprise Challenges

This section highlights four issues in governance, policy, and oversight that directly affect the readiness and resiliency of the MIB.

Alignment of Roles and Responsibilities of JMC and JPEO A&A: JMC is chartered as a joint organization that has oversight of the GOGO/GOCO portion of the MIB. Although its mission is intended to support the joint force, JMC is functionally an Army organization; Army personnel fill its leadership positions, and its facilities are predominantly Army owned.⁴⁷ Thus, the Munitions Seminar assess that JMC focuses more on common munitions needs and allows the services to manage their unique requirements. Finally, there is uncertainty in the relationship between JMC and JPEO A&A; the boundaries of responsibilities are not always clear.

SMCA Construct: The SMCA construct does not include the entire organic DoD munitions footprint. As previously mentioned, the Navy maintains two organic GOGO energetics entities. The largest of the two, Indian Head, MD, maintains the capability to augment the MIB through full-scale energetics R&D, prototyping, manufacturing, and disposal. However, unlike the Army GOGO/GOCOs, Indian Head, MD is not managed as part of the SMCA. Under the current SMCA construct, if the Army GOGO/GOCOs cannot meet demand, COCOs are asked versus these Navy GOGOs. Indian Head has the required facilities and capacity, but the current acquisition system does not treat them as part of the organic MIB capability. Indian Head is only used as a last resort.⁴⁸

Uncertain Funding and Demand Signal: Munitions producers note that uncertain and changing requirements, coupled with a lack of multi-year munitions purchases lead to unpredictable swings in production demand. As with other defense procurements, annual requirements change based on numbers of munitions forecasted to be consumed in combat and training. With declining profit margins, many sub-tier suppliers have shut down underutilized production lines, leaving prime munitions contractors wanting for supply sources. The uncertainty of large volume fluctuations adversely impacts MIB planning, operations and investments, competition, and ability to surge.⁴⁹ Steady, level production demands would go a long way to shoring up MIB production capabilities.

Administrative Burden: The large administrative burden that comes with doing business with the DoD is also a major concern for MIB producers. Complying with Federal Acquisition Regulation requirements, dealing with government bureaucracy, and addressing increasing environmental restrictions drive up product costs and increase contractor risk. Increased demands of cybersecurity only add to this burden. These additional costly requirements can act as a barrier for new and smaller market entrants who may choose not to enter into contracts with the DoD.⁵⁰

Intellectual Property

The disposition of intellectual property (IP) rights is a source of contention between the government and industry contractors. On some projects, R&D is funded by the DoD. When contracted for production, manufacturers are often hesitant to sell IP rights to the government for fear they will release it when competing future contracts.⁵¹ The DoD point of view is that because the technology was developed using government funds, the government should own the IP. IP ownership allows the government full control over the use of new technologies and can share that technology with multiple bidders when issuing requests for proposals. Ownership of specific technologies allows the government to inspire competitive prototyping among multiple contractors using the same baseline requirements.

However, industry partners believe funding alone should not dictate IP ownership. Companies maintain their time and specialized expertise lead to new technologies and want IP ownership to maintain a competitive advantage in any future contracts of those technologies. While government funding is critical for many companies to advance research and development, industry is incentivized by the prospect of their investments leading to future contracts. IP ownership provides an assurance that R&D efforts will achieve a return on investment of their time and expertise.

Human Capital

The MIB manufacturing labor pool has declined due to a decrease in the number of overall manufacturing jobs, drug and security clearance issues, and the inability to attract science, technology, engineering and mathematics (STEM) skills to rural areas. National trends in declining manufacturing jobs are a major concern for the MIB. September 2019 U.S. Bureau of Labor Statistics indicate a bleak and continuing trend in declining manufacturing jobs, which reflects challenges in human capital within the MIB.⁵² In 2008, the manufacturing sector had

approximately 9% of all U.S. employment which dropped to 7.9% in 2018. By 2028, statistics anticipate further decrease to 7.1%. Today's manufacturing output is at least five percent greater than it was in 2000, but it has become much more capital intensive and much less labor-intensive. Therefore, there are far fewer manufacturing workers overall, with about 7.5 million jobs lost since 1980. These job losses have likely contributed to the declining labor force participation of prime-age (between the ages of 21 and 55) U.S. workers.⁵³

Like many defense industries, the MIB is sometimes challenged in finding qualified workers that pass a drug test and can obtain a security clearance. In *The Transformation of Manufacturing and the Decline in U.S. Employment*, Research Associates at the National Bureau of Economic Research Kerwin Kofi Charles, Erik Hurst, and Mariel Schwartz studied the correlation between the overall manufacturing decline in the 2000s, and rising local opioid use and deaths. The opioid epidemic, compounded by the legalization of medical marijuana in several states, may explain the problems rural manufacturing companies are facing facilitating drug tests. The study found “opioid drug use has risen in areas hard-hit by manufacturing decline may have implications for future employment prospects in these areas. To the extent that these workers become addicted to drugs, which they might have taken in the first place because of the shock of a job loss, their likelihood of getting and retaining a job in the future will be lower.”⁵⁴ Whether opioid addiction led directly to a decline in labor or the decline of job opportunities exacerbated opioid addiction, the correlation is undeniably affecting rural communities and the ability for U.S. manufacturers to fill human workforce needs.

Stakeholders noted that a lack of trades workers and engineers is also a major concern to their operations.⁵⁵ Due to inherent security and accident risks related to munition production, many MIB facilities are located in rural areas of the country. Being able to attract licensed engineers and skilled labor-particularly welders-to such locations has at times been a challenge.⁵⁶ To combat the lack of trade skill workers, many MIB entities have initiated cooperative programs with local high schools, trade/vocational schools, community colleges. One such relationship is between MIB stakeholders working out of the Highland Industrial Park and Southern Arkansas University Tech in Camden, AR. Southern Arkansas University Tech has gone to great lengths to add and customize areas of study to meet demand from local MIB businesses.⁵⁷

On a positive note, nearly all companies report high employee retention levels due to close-knit work environments, multi-generational employee loyalties, and competitive benefits. Unfortunately, many MIB facilities are facing a rapidly aging workforce. For example, 40% of General Dynamics' employees in their Red Lion facility could retire in 5 years, and 23% of Northrop Grumman's Allegany Ballistics Laboratory employees are now retirement eligible.⁵⁸ To combat a potential skills gap as well as a retirement gap, many GOGO/GOCO/COCOs have undertaken robust in-house training programs. In-house training allows the firms more flexibility in focusing on the areas most needed. Numerous firms noted their ability to shift workers between different production areas when workflows increase or decrease.

Supply Chain and Resourcing Challenges

Access to a reliable and steady supply chain was noted as an area of concern for all MIB manufacturers. Successful MIB production requires the use of many rare earth elements (REE) and unique chemicals to produce propellants, explosives, and other munitions components such as fuzes. Lack of a reliable supply chain has resulted in extended lead times for some REE, chemicals, and other crucial MIB components. MIB members agreed they would prefer to procure materials domestically or from close allies, but sometimes that cannot be done. In some cases, China is the only available source for REE and specific chemicals. The 2018 DoD report, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*, noted this a specific risk to the MIB and efforts are underway to reduce dependencies on China and other foreign markets.⁵⁹

Many domestically produced chemicals needed for munitions production are only produced by a few suppliers or are even sole source items. One such example is ammonium perchlorate, an oxidizer used in the manufacture of solid-fuel rocket propellants. American Pacific Chemical is the sole manufacturer in the U.S. and is the supplier to both Northrop Grumman and Aerojet Rocketdyne. The current position appears to be that even if additional domestic or allied sources became available, the time and costs associated with the government-mandated first article and qualification testing is a major prohibitor.⁶⁰ It is often not a viable option to take already stressed production lines down to qualify new sources. Another critical chemical is nitric acid, the precursor for nitrocellulose propellants and some explosives. Supplied in large quantities to Radford and Holston AAPs, nitric acid from a refinery in El Dorado, AR is the sole source for this product. When this facility had production issues in 2015 due to damage from severe weather, the production of key munitions was delayed for months.⁶¹

Government policy decisions can also have negative effects on global supply chains. For example, recent tariffs enacted by the federal government increased demand for some domestic suppliers, thereby making it harder for MIB producers to secure resources in a timely matter.⁶² Varying demand signals from the DoD and uncertain funding make procuring long lead time supplies a large risk for the MIB.

Visibility into sub-tier suppliers is another area of concern for many manufacturers. Many sub-tier suppliers do not provide records of component sources to include the origin of components. This can lead to increased cybersecurity vulnerabilities and risk of counterfeit materials from offshore. Every supply chain touchpoint represents a potential risk to the MIB.⁶³

A final consideration is the increasingly specialized nature of munitions and how they are packed, stored, and moved. These developments have increased the need for specialized PHST. This, in turn, drives the creation of new handling equipment and procedures to address the redefined characteristics of containerized ordnance. Insufficient PHST can have significant impacts on safety, logistics, and warfighter readiness.⁶⁴

VI. Outlook and Innovation Environment

As the U.S. and its allies continue to engage in conflicts around the world and prepare for major conflicts, maintaining the health of the MIB is of the utmost importance. While there are vulnerabilities in the current MIB, the U.S. government has taken note and has pursued a roadmap to enact required fixes. As previously mentioned, Holston AAP, TN, and Radford AAP, VA, are both starting to receive long-overdue repairs. In addition, efforts like the EO 13806 task force are going a long way to identify shortcomings and highlight the need for further fixes to the industrial base. Finally, proponents of the MIB have begun to organize into forums structured for the open exchange of government and Industry views related to the munition areas.

Proponents of the MIB

The National Defense Industrial Association (NDIA), a non-profit dedicated to driving dialogue in key areas of national security has been a strong advocate of the MIB.⁶⁵ The NDIA has established the Industrial Committee of Ammunition Producers, where members of the munitions community and interested government agencies can take part in the following:

1. Review government munition acquisition policies, procedures, and actions.
2. Report on the health of the various sectors of the munition industry.
3. Identify and remove impediments to sustaining a responsive munition industrial base.
4. Provide a platform for identifying issues related to the munitions life cycle, from development through disposal.⁶⁶

Additionally, the self-organized Munitions Industrial Base Task Force (MIBTF) has been active since 1993, advocating on behalf of the MIB. The MIBTF is made up of a group of 15 companies working towards a common goal of “adequate funding and policies to sustain a responsive, capable U.S. MIB to develop, produce, and support superior munitions for the U.S. and its allies.”⁶⁷

EO 13806 MISSILES AND MUNITIONS WORKING GROUP RECOMMENDATIONS

The Department should:

1. Coordinate and fund obsolescence planning and mitigation.
2. Seek better visibility into sub-tier suppliers and develop better mechanisms for issue notification.
3. Fund the design and prototyping of new systems to keep design skills relevant.
4. Stabilize funding that provides a consistent demand signal to industry (at least at minimum sustaining rate production), allowing them to plan and maintain capacity and capability (and to maintain some level of surge capacity), and to maintain and improve existing

Ability to Surge

Another area to consider when evaluating the outlook of the MIB is its ability to surge during times of high demand. Most areas of the MIB evaluated for this paper indicated they had some limited ability to surge but face barriers including:

1. Single points of failure in the supply chain. In a 2016 report, the Army identified over 300 single points of failure in the MIB.⁶⁸ Energetics produced at Holston AAP and Radford AAP are prime examples. Currently, Holston AAP cannot produce enough RDX to meet warfighter needs. As a result, the DoD has been forced to buy the less desirable explosive, TNT, from overseas suppliers for use in bombs.⁶⁹
2. Access to a trained workforce to support surge operations.
3. Readily available access to long-lead items from sub-tier suppliers
4. Years of market uncertainty and large volume fluctuations have impacted production line capacities and investments. While most GOGO and GOCO suppliers have maintained some excess production line capacity, COCOs have had little incentive to maintain excess overhead costs.

Mobilization Readiness

When the MIB cannot meet the demand, the U.S. may need to mobilize. As mentioned above, the ability to surge is already vulnerable, so addressing the outlook of future mobilization is vital to national security. Below are what we assess to be the top concerns to mobilize the munition industry:

1. Invest in R&D via public-private partnerships to meet future demands. This synchronization of effort could leverage technology to quickly respond to increased demands.
2. The ability of the industry to recognize the demands for national security products and services and respond effectively.
3. Creation of a larger network of non-domestic global suppliers to secure production capabilities.

Emerging Technologies:

The munitions sector will also benefit greatly from emerging technologies, especially in the next 5-10 years. An emerging technology that has gained high interest recently is directed energy weapons. The Directed Energy Professional Society defines directed energy weapons as, “technology and weapon systems based on the application of force on target with electromagnetic energy vice kinetic energy (no projectile).”⁷⁰ All four branches of the DoD and U.S. Special Operations Command have ongoing efforts pursuing directed energy weapons. Directed energy weapons may still be a few years out, but the DoD proposes to spend more than \$993 million on these efforts in the FY2021 budget.⁷¹

The Joint Non-lethal Weapons Directorate (JNLWD), located on Marine Corps Base Quantico, VA, is also focused on emerging technologies. The JNLWD serves as a focal point for technical and programmatic guidance of current and projected joint non-lethal weapons technologies.⁷² Whereas traditional munitions development typically focuses on use during Phase III military

operations (dominating activities), JNLWD works towards developing non-lethal intermediate force capabilities for use during other phases of military operations such as grey zone operations.⁷³

VII. Essays on Major Munitions Issues

Strategic Partnerships and Foreign Military Sales

The Impact of Partnerships and Allies on the U.S. MIB

Issue:

The U.S. maintains strong relationships with allies and partners around the world. These relationships are characterized by military collaborations, and trade and defense agreements. U.S. foreign policy is shaped by the mutually beneficial transactional relationships these agreements produce. As a result, the U.S. can project power, strengthen the reach of American defense firms, and spread American influence. Furthermore, the U.S. furthers its influence by mandating that foreign aid given to nations must be used with U.S. defense firms. In particular, the munitions industry is bolstered by this practice.

Discussion:

Through a policy of focusing foreign aid back to U.S. defense firms, the U.S. can effectively garner significant military, economic and political power. This form of international cooperation is a product of common interests that are dynamic and must be shepherded. Great power competition and the proliferation of Russian and Chinese influence threaten U.S. primacy abroad and erode our ability to project power anywhere we choose, any time we choose. As an example, the assistance that China and Russia have provided to some European countries during the COVID-19 pandemic is a sign that these powers can stand alongside other countries when they are in need.⁷⁴

Recommendations:

1. The U.S. and its allies should refine the processes associated with acquisition and procurement. The efficiencies generated through such improvements would ensure that the latest technologies are available for the U.S. force and their allies as quickly as possible.
2. U.S. primacy and the effectiveness of its allies and partners are bolstered by the ability of partner nations to provide a viable threat and deterrence for their adversaries. As such, there has to be strong confidence in the ability of the MIB to meet the demands of emerging threats. This confidence can only be garnered through reliable supply chains. The U.S. must leverage allied and partner nations to provide redundant sourcing and capacity for the most critical components and manufacturing needs.
3. Furthermore, the U.S. should leverage common research areas among allied nations industries, research institutes, and universities. Shared challenges and common interests among

partners translate to collaborations and generate mutual commitment. These collaborations also create intellectual property partnerships, as well as joint production that contributes to the expansion of the U.S. labor market.

Authors: Col Neri Horoviz, Col Alvin Luzon, and Col Herry Simanjuntak

Supply Chain

Single-Point Failures in the Munition Industrial Supply Chain

Issue:

The munition industrial supply chain presents the greatest vulnerability across the entire MIB. This is due to a supply chain that is “dominated by sole- and single-source suppliers.”⁷⁵ Furthermore, many of those suppliers are from near-peer competitor and adversarial nations, such as China. This means that any one supplier, no matter the significance or cost, could halt the production line of a munition. The DoD must construct a long-term policy to eliminate these supply chain risks during both peacetime operations and war.

Discussion:

The U.S.’ munitions industry relies on a global supply chain to effectively produce and deliver munitions to the warfighter. Unfortunately, the DoD lacks the needed oversight of the complex supply chain, and numerous events have occurred displaying the vulnerable and non-transparent nature of the supply chain. For example, in 2018 the sole-source provider of dimethyl diisocyanate, a critical propellant component used in the Advanced Medium-Range Air-to-Air Missile (AMRAAM) and the AIM-9X air-to-air missiles, unexpectedly notified the DoD that it was stopping production leaving no qualified provider.⁷⁶ This created a void in the upstream production of the missiles until a new supplier could be qualified.

Additionally, the DoD does not maintain a sufficient reserve of these materials. The Joint Munitions Command estimated that depending on the material, producers would only have enough material to support a surge from one week to five months. This assumes that the suppliers are still providing materials at their contracted rate. The surge sustainment length is cut drastically when a supplier stops production completely.

Recommendations:

1. Prioritize qualifying and utilizing second-source suppliers for materials from foreign sole- and single-source companies that are not at high risk for trade embargoes, natural disasters, war, or companies from competitor nations such as China. These second-source suppliers should then be maintained in a “warm status” by utilizing them for about 10% of the overall material demand. This strategy would increase the U.S.’s capability surge while keeping costs down by continuing to leverage most of the material supply from less expensive foreign companies.

2. Implement a policy that establishes a database and standardized reporting metrics for all suppliers, and eliminate last-minute production surprises (e.g., AMRAAM and AIM-9X) by providing DoD and the MIB with greater supply chain oversight.
3. Develop strategic stockpiles for high-risk sole- and singled-sourced raw and synthetic materials.
4. Pre-negotiate contracts annually with companies that are already making the desired materials, to expedite the qualification timeline should a material shortage be realized.
5. Ensure all government contracts require prime contractors/suppliers to build in additional production capacity (i.e., supply chain, infrastructure) to meet surge and mobilization requirements.
6. Expand the strategic stockpile of munition end-items the sole- and singled-sourced raw and synthetic non-metal materials support in case these supply chains get temporarily interrupted.
7. For current munitions efforts, the government must negotiate with sole-source suppliers for the material IP, data rights, or technical data packages.
8. The U.S. must contract to receive all relevant technical data needed to produce future munitions efforts that require raw and synthetic materials by foreign sole-source suppliers.

Authors: Lt Col Mike Baker and Lt Col Scott May

Rare Earth Element Supply Challenges

Issue:

China's monopoly of the world's manufacturing sector and near-complete control of the global REEs supply is the impetus for further erosion of the U.S. MIB.^{77,78} U.S. mines contain some of the needed REEs, but they lack the necessary infrastructure and domestic processing capacity which poses a significant vulnerability to our defense supply chain and threatens U.S. national security and that of its allies.

Discussion:

Chinese control of the REE supply chain seeks to undermine U.S. and global economies, as well as the U.S. defense MIB. Every advanced weapon in the U.S. arsenal from advanced fighters to destroyers and submarines, missiles, precision-guided munitions (PGMs), smart bombs, and nearly everything in between, is completely reliant on REEs.⁷⁹ To regain control of this vital ecosystem, the Pentagon performed a major review of the defense industrial base in 2018 and singled-out REEs for munitions and missiles as a top concern.⁸⁰ From this review, President Trump issued five presidential determinations that DoD develop a new rare earth capability.⁸¹ On July 22, 2019, President Trump made official determinations under Section 303(a)(5) of the Defense Production Act (amended, 50 U.S.C. 4533), regarding the shortfall of capabilities within

the defense industrial base to produce multiple categories of REEs. These Presidential Determinations stated that domestic production capability for specified rare earth metals and alloys are “essential to the national defense.”⁸² Additionally, President Trump signed EO 13817 “A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals.” This EO characterized these minerals as “critical” and established significant governance to ensure their security.⁸³

Recommendations:

1. The DoD should create a Joint Munitions Integrator under the Undersecretary of Defense for Acquisition and Sustainment to provide a whole-of-nation approach to critical materials and ensure there is information sharing among all stakeholders. Today, all DoD service components address these challenges separately, which does not allow for adequate oversight. A joint office under Industrial Policy would better address this vital ecosystem.
2. The U.S. should work to increase new and more diverse domestic sources in the supply chain for REEs. The U.S. must actively pursue bilateral and multilateral agreements with allies like Australia, Canada, Japan, Norway, and others, to diversify its sources. The U.S. must build mutually beneficial relationships with allies to mitigate the threat China poses in REE production and processing.
3. The U.S. should significantly increase research and development funding and investment to rebuild domestic sources of supply and processing for REEs and all materials deemed critical to U.S. national security. The U.S. should also seek out or create alternate REE sources, as well as further research in composite materials and innovative manufacturing processes.

Authors: Mrs. Chantele Dow

MIB Resiliency**Transformation from MIB TO MITB****Issue:**

As a significant part of the U.S. National Technology and Industrial Base (NTIB), the MIB must enhance advanced technology integration and insertion (e.g., additive manufacturing) to strengthen readiness, reduce vulnerabilities and optimize for sustainment and surge.

Discussion:

MIB infrastructure viability is a critical consideration for the future of U.S. military effectiveness. The legacy nature of the MIB compounded by decades of low funding prioritization has led to a system that is bottlenecked, fragile, aging, and not optimized for future surge requirements in an era of great power competition. In 2018, Executive Order 13806 directed a whole-of-government effort to identify and evaluate risks in the manufacturing and defense industrial base.⁸⁴ The outcome of this comprehensive analysis was captured in the commonly known "806

Report." Critical findings in the report included a need to transform the munitions ecosystem to improve functional processes, enhance sustainment, and maximize output.

The focus must shift to investing in a modernized technology-driven infrastructure. Advanced emerging technologies (e.g., additive manufacturing) and production platforms would accelerate the advanced development and delivery of key capabilities such as insensitive munitions, new energetics, hypersonics, and precision-guided long-range capabilities. The net effect would transform the MIB to a Munitions Industrial Technology Base (MITB) where technology guides investment.

The outcome of improving the infrastructure capabilities to strengthen MITB through technological superiority and complementary growth with strategic partner industrial capacity would be a competitive advantage. This MITB would be more flexible, agile, and globally competitive. The technological implication would change the munitions enterprise framework allowing the U.S. to maintain leadership in this critical node of the global defense network.

Recommendations:

1. Transform the current MIB to a MITB as a part of NTIB (see Appendix D). The proposed MITB ecosystem would both facilitate the development of high-tech investment and build networks of innovators and entrepreneurs as well as civil and military human capital across the national industrial enterprise.
2. Expand the current DoD Critical Energetic Materials Working Group into an interagency task force known as the Munitions Industrial Technology Base Task Force with senior administration leadership (e.g., Secretary of Defense) oversight. As part of the Coronavirus Aid, Relief and Economic Security Act and follow-on stimulus packages, expend funds targeting defense critical infrastructure to modernize the MITB.⁸⁵ Capitalize on the stimulus as a means of funding specified MITB projects like additive manufacturing and insensitive munitions production while divesting legacy systems and facilities.

Authors: Col Nikolay Nikolov and Mr. Don Phillips

Human Capital

Human Capital Challenges and Opportunities in the U.S. Munitions and Manufacturing Base

Issue:

The MIB must strengthen its human capital by aggressively pursuing novel recruitment efforts, investing in advanced technologies and automation, and creating value in the rural communities that support manufacturing.

Discussion:

The U.S.'s DIB faces unprecedented human capital challenges, particularly in its munitions and manufacturing sectors. Department of Labor statistics reveal significant declines within the

manufacturing sector—over 7.5 million jobs since 1980.⁸⁶ The common challenges across the MIB include a skills-gap with a rapidly retiring workforce, and workforce reliance on rural communities with weak labor markets, drug use, and limited educational opportunities for skilled education.⁸⁷

The U.S. manufacturing sector should embrace the dawn of a new manufacturing labor workforce by creating value in its human capital. By investing in the advanced cross-training of current employees, partnering with technical schools to leverage STEM internships, and embracing emerging technology, the munitions industry can inspire innovation and use automation as a means to significant macroeconomic advantages in the communities that support them.

Recommendations:

1. In addition to continuing aggressive recruitment of STEM-based students, the U.S. MIB should look to novel recruitment strategies to incorporate women into non-traditional positions. According to the Department of Labor, as of December 2019, women are now most of the college-educated labor workforce in the U.S. and are expected to become the majority of the total workforce in the coming years.⁸⁸ Even among non-college educated sectors, such as mining, trends reveal that despite a decline in overall mining and manufacturing jobs, women's participation in these sectors is growing.⁸⁹ However, though many manufacturing companies aim for higher diversity amongst their workers, women comprise less than 30% of the total U.S. manufacturing workforce.⁹⁰ By increasing recruitment of college-educated women, the munitions industry can broaden the scope of their application pool.

2. The U.S. munitions base must fully embrace and invest in automation to the maximum extent possible. The next generation of manufacturing will require a shift in thinking from using human capital to perform the jobs that automation can now perform to one that utilizes human capital to value and reward its human capital for risks and innovation. With the advent of emerging and advanced technology, the very process of manufacturing is entering into a new age of modernization. Emerging technologies bode well for manufacturing companies. Increased reliance on automation and advanced technology, such as 3D printing, can allow industries to offer a higher salary to the skilled and college-educated workforce. Focusing on advanced technology may initially cause a decrease in employment, particularly in unskilled labor, but the result of higher-paid employees will result in a boost in the macroeconomic status of its communities.

Author: Mrs. Linda Minsker

Munitions Requirements

The Munitions Requirements Process: Charting a Munitions Path for Great Power Competition That Works

Issue:

The DoD utilizes the Munitions Requirements Process (MRP) to derive the quantities of each of over 6000+ munitions in support of training and operational requirements. The MRP provides for a Total Munitions Requirement (TMR), which is the “sum of all munitions requirements, to include the sum of war reserve munitions requirement, and training and testing requirement.”⁹¹ The DoD should refine its processes to capitalize on opportunities to improve the MRP to provide a better context and understanding of the munitions requirements needed for great power competition.

Discussion:

The munitions requirements process is the foundational process from which we derive our munitions stockpile and determine the acquisition/production dynamics required to keep that stockpile healthy, responsive, and ready. The predicate for these assessments is derived from how we characterize risk. The composite of these efforts will provide the DoD far better standing when it comes to how we mutually understand the capacity of our munitions stockpile to satisfy our needs and provide clear expectations of what industry must do to provide those expectations.

Recommendations:

1. The DoD should enforce homogeneity through the lens that the combatant commands and the Joint Staff use to view service munition projections and assessments. By extension, this homogenous lens should serve as a mechanism for the Joint Staff to assess, and OSD to decide/validate/approve munitions acquisitions for the Services. Harmonizing the roles the Joint Staff and OSD play for the significant investments made for such finite resources is fundamentally critical to ensuring that the munitions required for the next fight are ready and available for the combatant commander.
2. The DoD should implement a more comprehensive methodology for assessing targeting. The MRP should use a ‘recursive methodology’ with which to apply the weapons to the target identified in the Phased Threat Distribution. There is a strong potential for the greatest utility to be found in asking each Service to look at each sub-phase of conflict and collectively gather to ensure that the overall intent and best outcome is achieved at each step. A process like this provides a mechanism for the greatest efficiency in the use of the finite precision-guided munitions stockpile, and more importantly, a more deliberative, iterative process to determine that the U.S. forces are best postured for success through each phase.
3. The MRP should also reflect the intent of the National Defense Strategy and the character of globally integrated operations. The MRP should be used to create two separate, comprehensive assessments, based on our two major threats, so DoD can truly embrace the risk of simultaneity

and create an allocation of preferred munitions and allow for many other munitions to be retained in reserve to mitigate other threats. This has the benefit of creating a metric to gauge the quality of the TMR derived from the current MRP, ultimately providing a clear characterization of the risk associated with the munitions stockpile.

Author: COL LaHavie Brunson

Lethality

Building a Lethal Force - Munitions Modernization Policy Needed to Drive Replacement of Cluster Munitions

Issue:

Munitions are a fundamental requirement for a lethal force, but munitions programs risk getting left behind in resourcing. In particular, the DoD needs a stronger policy on cluster munitions to assure the force can deliver the critical area effects needed for a near-peer fight without the operational hazards and humanitarian concerns that result from the high dud rates of our current inventory. The services' progress will continue to be slow without a DoD policy to force the modernization of cluster munitions.

Discussion:

DoD policy on cluster munitions use and development has wavered over the last 20 years. The current policy allows retention of existing cluster munitions until the services procure a suitable replacement, but gives no suspense date for developing the replacement.⁹² Little incentive exists for the services to accelerate or prioritize their replacement programs, so they continue to accept risk in resourcing for munitions,⁹³ focus on precision-guided weapons, and make outsized investment in niche weapons.⁹⁴ This increases the risk that industry innovation in improving cluster munitions may stall.

In addition to the humanitarian concerns of unexploded ordnance, the high dud rates of cluster munitions pose a significant operational hazard to our forces. However, cluster munitions remain valid for military use and represent some of our best capabilities. As such, the DoD policy appropriately focuses on retaining the capability, but it lacks a strong timeline, lacks nuance in its blanket 1% unexploded ordnance standard, and constrains development with overly specific technical requirements for submunitions (bomblets, grenades, or mines dispersed by a larger munition).

A stronger policy on cluster munition modernization will have a limited effect on the DIB's capability to support the execution of the defense strategy, to surge, or to mobilize. New cluster munitions requirements may increase the complexity of loading, assembling, and packing operations, but the industrial base has the necessary skills, equipment, and facilities. Technical specifications will increase demand for advanced microelectronics (a fragile market due to hardening requirements) and small batteries.⁹⁵ The requirement for internal power sources will also reduce shelf life and affect munitions inspection and maintenance requirements.

Additionally, the submunition standards will affect material testing and require more test articles. The new policy will likely have marginal impacts on human capital and governance. Overall, the primary concern will be for the services to prioritize and adequately resource replacement programs.

Recommendation:

A DoD policy is required to drive service efforts since funding pressure will likely remain. The DoD should conduct a detailed review of operational concepts and requirements across all services and portfolios to develop a broad munitions modernization policy. As part of that effort, the DoD should revise its cluster munitions policy to be more in line with the 2008 version. Specifically, the policy should establish a more directive timeline for the development of replacement munitions, develop a more nuanced reliability standard, and set guidance limiting recapitalization or conversion of current munitions until replacements are on hand.

Author: COL Joseph Munger

Navy Energetics**Forgotten Capacity: The Naval Energetics Industrial Base Capability****Issue:**

The MIB faces several challenges that could impact readiness: the quantities of the munitions stockpile are dwindling, the age of the munitions is increasing, and the manufacturing equipment is old, obsolete, and expensive to operate. These challenges raise concerns that the Industrial Base will not be able to meet increased requirement demands in the event of a national emergency, which could require a surge or mobilization in munitions production.⁹⁶ The Army currently acts as the SMCA for the MIB. However, the organic munitions manufacturing capability of the Navy has not been considered for increased production. The MIB can meet a requirement to surge and mobilize, especially if the Department of Defense uses the Navy energetics industrial capability to supplement current capacity.

Discussion:

The MIB is critical to fulfilling the National Defense Strategy. That is why the Navy has always maintained (even if minimal) an organic munitions manufacturing capability.⁹⁷ Today's Naval munitions infrastructure consists of four naval weapons stations: Seal Beach, CA, Yorktown, VA, China Lake, CA, and Earle, NJ; two naval munitions depots: Indian Island, WA, and Crane, IN; and a naval arsenal, Indian Head, MD. Naval Weapons Stations maintain and repair, store, and issue munitions. Currently, only the Army has munitions manufacturing plants that produce for the Department of Defense. Unfortunately, over the past several decades, funding to these manufacturing facilities has been reduced rendering munitions manufacturing capabilities insufficient to meet an anticipated surge or mobilization demand.

The center of the Naval munitions infrastructure is located at Naval Surface Warfare Center Indian Head, MD.⁹⁸ Indian Head's mission is to research and develop; test; manufacture and

support energetics.⁹⁹ In 2014, the Secretary of the Navy designated Indian Head as an arsenal,¹⁰⁰ which authorizes Indian Head to maintain munitions production and sustain the capacity needed to meet surge and mobilization demands.¹⁰¹ This capability could be utilized to augment the MIB production capacity as needed.

Recommendations:

1. Navy leadership has previously made the following recommendations: (a) include Indian Head in the DoD Manufacturing Arsenal planning process, (b) develop a Naval energetics acquisition strategy to drive munitions research and development efforts based on emerging threats and maintain the Navy's organic manufacturing capabilities, and (c) establish policies that prioritize a healthy organic energetics capability.¹⁰² These efforts will supplement the Defense Department's potential increased munitions production requirements.

2. The DoD should renew focus and funding to reinvigorate the Industrial Base to meet anticipated future surge and mobilization requirements. The entire scope of organic production capabilities should be included in munitions planning. The Navy, through Indian Head, has an organic capability to produce munitions, especially RDX, that can supplement the Army's production at Holston AAP, TN. The Navy's capability seems to be a forgotten capacity that could be used to augment the MIB to meet increased requirements. There is no appropriation or contracting barriers, nor requirement disparity causing the oversight in munitions planning; it is most likely a result of service parochialism that should be easily overcome for the sake of national security.

Author: Mrs. Angela Bonner

VIII. Areas for Future Consideration

The scope of this study was not all inclusive due to the to the limited time allotted and the vast scale of the MIB. COVID-19 related travel restrictions also impacted the assessment. A more complete picture of the MIB could be gained by conducting further study on the following topics:

1. Explore technical components of munitions (e.g. electronics, fuzing, circuits), their supply chain, and sourcing.
2. Revamp MIB governance in light of great power competition.
3. Explore hypersonic weapons and their place of future prominence in the DoD's munitions portfolio.
4. Review the impacts of a post-COVID-19 reduced DoD budget and the National debt.
5. Consider expansion of the NTIB to benefit the MIB; increase emphasis on the role of allies and strategic partners in innovation and technology development.
6. Evaluate how nonaligned nations and emerging economies can impact the MIB.
7. Conduct a net assessment of allied and competitor MIBs to determine/develop best practices.
8. Proactively utilize the Defense Production Act authorities to drive improvements of the MIB.

9. Determine areas for mandatory government investment in critical areas/materials of the MIB.

IX. Conclusion

As revealed in the response to EO 13806, the MIB is at a critical juncture. While prime contractors are largely able to satisfy their roles in the MIB, challenges in areas such as administrative burden, uncertain demand signals, and human capital are ever lingering concerns. The GOGO and GOCO facilities are in even more tenuous positions. Due to years of neglect and a lack of modernization, many are barely able to keep up with demand, and in some cases are woefully behind. The government must prioritize efforts to revitalize and restore aging arsenals and production facilities. Finally, fragile supply chains throughout the MIB, often dependent on overseas and sole-source vendors, exacerbate risk in the already delicate ecosystem.

The shift of America's National Defense Strategy towards countering great power competition conveys an ever more compelling need to safeguard the nation's organic munitions industry. While the mission of America's military has expanded over time, its very core is the ability to hold our adversaries at risk by threat of causing great harm. To be able to carry out this mission, few parts of the industrial base are more important to the warfighter than the munitions segment. A hollow MIB brings great risk of a shortfall in a major theater war and a dubious ability to surge and mobilize if needed.

The recommendations provided in this study are not an exhaustive list of what needs to be done, but rather serve as an impetus to initiate action to shore up and expand the MIB. The MIB must not only focus on evolutionary capabilities, but must also be fervently seek efficiencies, explore emerging technologies, adapt to advanced production techniques, and revitalize existing infrastructure. Anything less may leave the warfighter wanting. The DoD does not have the luxury to wait to act.

Appendix A: Organic Army Muniton Facilities¹⁰³

Installation	Location	Function	Specialty
Anniston Munitions Center*	Anniston, AL	Strategic Reserve	- Ammo Supply Depot Ops - Demilitarization - Missile Supply Depot
Blue Grass Army Depot	Richmond, KY	Distribution and Strategic Reserve	- Ammo Supply Depot Ops - Demilitarization - Chemical Defense Equipment
Blue Grass Chemical Activity	Richmond, KY	Strategic Reserve	- Chemical Weapons Stockpile
Crane Army Ammunition Activity	Crane, IN	Distribution and Production	- Ammo Supply Depot Ops - Demilitarization - 5"/54 & 76mm - Illum, Pyro, Flares
Hawthorne Army Depot*	Hawthorne, NV	Strategic Reserve	- Ammo Supply Depot Ops - Demilitarization
Holston Army Ammunition Plant*	Kingsport, TN	Production	- Explosives
Iowa Army Ammunition Plant*	Middletown, IA	Production	- Med. & Large Cal. Load, Assemble & Pack - Missile Warheads - C4 Extrusion
Lake City Army Ammunition Plant*	Independence, MO	Production	- Small Caliber - Perform Reliability Testing
Letterkenny Munitions Center	Letterkenny, PA	Distribution	- Ammo Supply Depot Ops - Demilitarization - Tactical Missiles - Missile Maintenance
McAlester Army Ammunition Plant	McAlester, OK	Distribution and Production	- Ammo Supply Depot Ops - Demilitarization - Navy/Air Force Bombs - Intelligent Munitions
Milan Army Ammunition Plant*	Milan, TN	Production	- Load, Assemble & Pack (Inactive)
Naval Air Warfare Center Weapons Division	China Lake, CA	Distribution and Strategic Reserve	- Store, Test, Refurb Naval Aviation Weapons
Naval Ammunition Depot Crane	Crane, IN	Distribution and Production	- Logistics, Repair, Overhaul, and Design of Small Arms Munitions
Naval Magazine Indian Island	Indian Island, WA	Distribution and Strategic Reserve	- Maintenance, Storage, and Loading of Naval Munitions
Naval Surface Warfare Center Indian Head	Indian Head, MD	Distribution, Production, and Strategic Reserve	- R&D, Test, and Manufacturing of munitions.
Naval Weapons Station Earle	Earle, NJ	Distribution and Strategic Reserve	- Maintenance, Storage, and Loading of Naval Munitions
Naval Weapons Station Seal Beach	Seal Beach, CA	Distribution and Strategic Reserve	- Maintenance, Storage, and Loading of Naval Munitions
Naval Weapons Station Yorktown	Yorktown, VA	Distribution and Strategic Reserve	- Maintenance, Storage, and Loading of Naval Munitions
Pine Bluff Arsenal	Pine Bluff, AR	Strategic Reserve and Production	- Ammo Supply Depot Ops - Smoke/Obscurants & Phosphorus - Chemical and Biological Defense Equipment - Smoke Ammunition
Pueblo Chemical Depot	Pueblo, CO	Strategic Reserve	- Chemical Weapons Storage/demilitarize
Quad City Cartridge Case Facility*	Rock Island, IL	Production	- Deep Drawn Cartridge Cases
Radford Army Ammunition Plant*	Radford, VA	Production	- Propellants
Scranton Army Ammunition Plant*	Scranton, PA	Production	- Projectile Metal Parts
Tooele Army Depot	Tooele, UT	Distribution and Production	- Ammo Supply Depot Ops - Demilitarization - Ammunition

* GOCO Facilities

Appendix B: Financial Analysis of MIB Prime Contractors¹⁰⁴

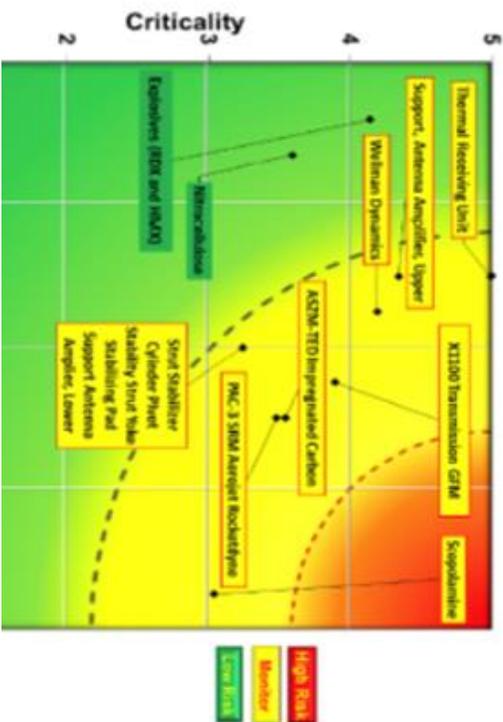
	ROIC ¹		Net Profit Margin ²		Debt/Equity Ratio ³		Current Ratio ⁴		WACC ⁵	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Lockheed Martin	40.40%	40.70%	9.40%	10.40%	10.12	4.05	1.1	1.2	8.60%	6.80%
Boeing	70.80%	-3.80%	10.30%	-2.30%	40.8	-3.17	1.1	1.1	10.90%	7.30%
Northrop Grumman	13.10%	19.40%	10.80%	6.60%	1.76	1.57	1.2	1.1	7.90%	6.40%
BAE	10.90%	14.70%	5.90%	8.10%	0.78	0.63	1	1	9.90%	7.30%
Raytheon	11.50%	12.80%	10.80%	11.50%	0.44	0.39	1.5	1.3	7.90%	9.29%
General Dynamics	18%	14.60%	9.30%	8.80%	1.06	0.88	1.2	1.2	9.70%	7.60%

1. Return on invested capital (ROIC) is a profitability ratio that measures the return a company earns on invested capital. The ROIC is a good indicator of how a company is using its money to generate returns.¹⁰⁵
2. Net profit margin is an indicator of how much income is generated as a percentage of revenue. Net profit margin highlights what percent of each dollar of revenue a company translates into profit.¹⁰⁶
3. Debt to equity ratio is a calculation of a company's total liabilities divided by its shareholder equity. It is a good indicator of if a company is financing operations through debt.¹⁰⁷
4. The current ratio measures a company's ability to pay short term obligations.¹⁰⁸
5. Weighted average cost of capital (WACC) is a calculation of a firm's cost of capital in which each category of capital is proportionately weighted. The WACC signifies the average rate of return a firm expects to compensate its investors. A higher WACC percentage is associated with a higher risk.¹⁰⁹

Appendix C: Army Materiel Command Assessment of MIB Vulnerability¹¹⁰

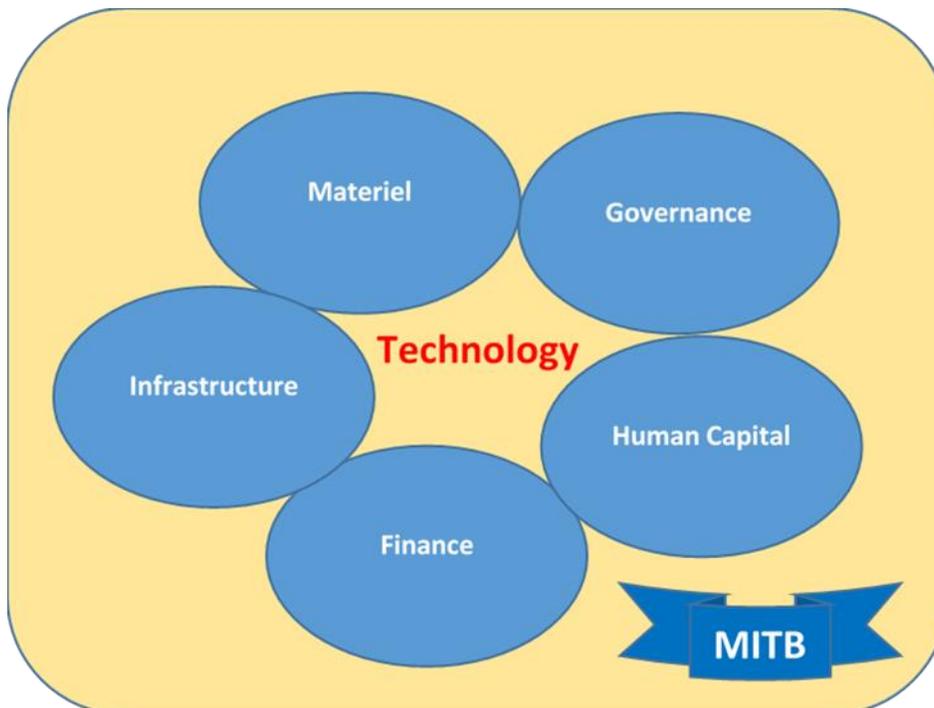
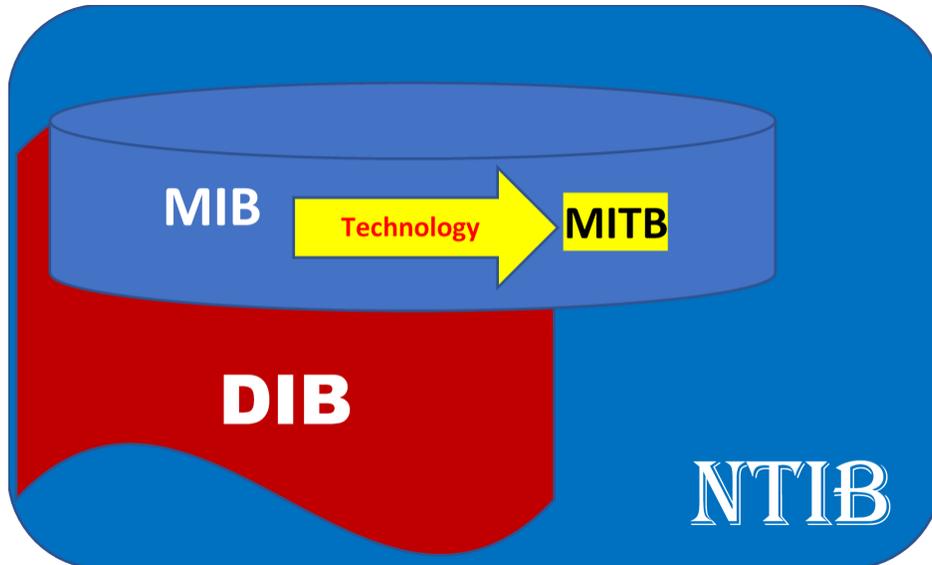


- ✓ AMC Industrial Base is healthy.
- ✓ No high risk industrial capabilities.
- ✓ All moderate risk industrial capabilities are visible to stakeholders and are being monitored for actions taken as needed to mitigate Readiness risks.



Appendix D: Munitions Industrial Technology Base

The transformation from MIB to MITB



List of Acronyms

Acronym	Page Number
AAP: Army Ammunition Plant.....	5
ABL: Allegany Ballistics Laboratory	v
AMC: Army Materiel Command.....	9
AMRAAM: Advanced Medium-Range Air-to-Air Missile	17
ARDEC: Armament Research and Development Center.....	6
AUR: all-up-rounds.....	4
AWCF: Army Working Capital Fund	9
COCO: Contractor Owned Contractor Operated	3
COVID-19: Coronavirus Disease 2019	4
DARPA: Defense Advanced Research Projects Agency.....	v
DASD-IP: Deputy Assistant Secretary of Defense for Industrial Policy	3
DIB: Defense Industrial Base	1
DoD: Department of Defense	1
DoDI: DoD Instruction	3
DTRA: Defense Threat Reduction Agency.....	v
EO: Executive Order	1
FEMA: Federal Emergency Management Agency.....	vi
FY: Fiscal Year.....	1
GAO: Government Accountability Office.....	9
GOCO: Government Owned Contractor Operated.....	3
GOGO: Government Owned Government Operated	3
HMX: High Melting Explosive.....	3
IM: Insensitive munitions.....	3
IP: intellectual property	11
JM&L LCMC: Joint Munitions and Lethality Life Cycle Management Command.....	6
JMC: Joint Munitions Command.....	v
JNLWD: Joint Non-lethal Weapons Directorate.....	15
JPEO A&A: Joint Program Executive Office Armaments & Ammunition	6
LAP: load, assembly, and packing	5
MIB: Munitions Industrial Base.....	1
MIBTF: Munitions Industrial Base Task Force.....	14
MILCON: Military Construction.....	9
MITB: Munitions Industrial Technology Base	20
MRP: Munitions Requirements Process	22
NDIA: National Defense Industrial Association.....	14
NTIB: National Technology and Industrial Base.....	19
NWCF: Navy Working Capital Funding.....	9

OSD: Office of the Secretary of Defense.....	v
PGM: Precision-guided munition.....	2
PHST: Packaging, handling, storage, and transportation	2
Primes: prime contractors	7
R&D: research and development.....	4
RDX: Royal Demolition eXplosive.....	3
REE: rare earth elements	13
ROIC: return on invested capital.....	28
SCM: Supply Chain Management.....	3
SMCA: Single manager for conventional munitions	3
STEM: science, technology, engineering and mathematics	11
TMR: Total Munitions Requirement	22
TNT: Trinitrotoluene	3
U.S.: United States	1
WACC: weighted average cost of capital	28
WWII: World War II.....	4

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