THE LAND WARFARE PAPERS

No. 113 AUGUST 2017

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Scott S. Haraburda

A National Security Affairs Paper
published on occasion by
THE INSTITUTE OF LAND WARFARE
ASSOCIATION OF THE UNITED STATES ARMY
Arlington, Virginia

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The Institute of Land Warfare
ASSOCIATION OF THE UNITED STATES ARMY

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LAND WARFARE PAPER No. 113, August 2017

Conventional Munitions Industrial Base

by Scott S. Haraburda

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Preface

Readiness is the Army's number one priority. It requires the strategic capability to procure and manufacture munitions when and where they are needed. Understanding how and why to do this requires a full understanding of the historical development of the American conventional munitions industrial base (CMIB), including a study of some of the devastating lessons learned along the way.

A chronic problem with which Soldiers struggled throughout most of the American Revolution was the shortage of munitions. During that war, nearly all of the shots and shells fired but only a meager 10 percent of the gunpowder used were locally produced. During the early years of World War I, European nations modernized weapons with machine guns, tanks, airplanes and larger artillery, leaving the American CMIB unable to supply munitions to these new weapon systems. This forced the United States to rely on foreign firms for most of its munitions requirements. By the start of World War II, the United States lacked a peacetime munitions industry; this forced the military to develop the capabilities of commercial manufacturing plants and training of its production personnel on its own. By the end of the war, the United States had constructed nearly 60 munitions manufacturing plants. Sadly, the nation was unable to support the munitions needs during the initial few years of the Korean conflict. During the Vietnam War, the CMIB consisted primarily of machines left over from World War II and representing technology from World War I. Today, the top commercial munitions managers concentrate more on bottom-line financial returns for their shareholders, increasing their share of the market, eliminating competition and reducing the number of available firms.

The American CMIB faces several challenges that could impact munitions readiness to Soldiers in the future. One of these challenges includes the quantities and age of the munitions in storage. Nearly a third of the almost 3,000 types of munitions are short of the required quantities and nearly one quarter of the stored munitions are more than 25 years old. The United States should conduct a comprehensive strategic review of its munitions and demilitarize those items it no longer needs. Another challenge is that much of the equipment in the CMIB government facilities is old, obsolete and expensive to operate, indicating capability concerns for sustaining the quality and quantity of munitions required for a prolonged national emergency. As such, the United States should decide which part of the CMIB should be saved and which part should be eliminated. The last challenge is its workforce; the skills involved in munitions-related production generally cannot be adapted to commercial application, nor can existing commercial production experience be converted to munitions productions. It is critical that munitions-manufacturing skills be preserved. The commanders of the government munitions plants should be given the authority to hire government workers to meet its workload and to mitigate anticipated losses through over-hiring.

Although not perfect, the CMIB supported the U.S. military successes from initial sovereignty more than two centuries ago to its undisputed global superpower position today. While it was good enough for the past, by and large, the question now is whether it will be good enough for future needs. Although it is not as necessary during long periods of reduced demand, when demand does increase, CMIB needs to be responsive, dependable and reliable. There is a crucial question facing the nation, the same question that it has had to answer repeatedly for more than two centuries: what can be done to ensure that the CMIB is given sufficient resources to sustain Army readiness?

Conventional Munitions Industrial Base

Every Infantryman, from the private enlisted Soldier, to the general officer, is first a rifleman. As such, he must be a master of his basic skills: shoot, move, communicate, survive and sustain. These basic skills provide the Soldier's ability to fight.

Field Manual 3-21.8[1]

Introduction

Readiness is the number one priority of the U.S. Army. According to General Mark Milley, Chief of Staff, U.S. Army, "Our obligation to the nation is to be ready, prepared, trained, manned, and equipped. . . . That's the reason why priority one is readiness and the challenges in front of us are pretty significant."[2] A key basic skill necessary for Army readiness is the ability to shoot, which involves supplying munitions to Soldiers when and where they need them.

To improve this readiness requires more than teaching Soldiers how to requisition and transport munitions on the battlefield. It requires a strengthening of the strategic capability to procure and manufacture them when and where munitions are needed. General Gustave Perna, commander of Army Materiel Command, says he will do this by aligning "workload in our depots, arsenals and ammunition plants to unit readiness, rapidly acquiring capabilities to meet materiel and sustainment needs while divesting those systems no longer required."[3] During a March 2017 meeting of the House Armed Services Subcommittee on Readiness, several senior flag officers reiterated the need for "a viable industrial base to sustain readiness."[4] The words of these senior Army leaders make it sound all too easy to improve Army readiness. But understanding how and why to do this for munitions requires a full understanding of the historical development of the American conventional munitions industrial base (CMIB) and the potentially devastating issues that have been conquered in its development.

Since its formation in 1775 when it embarked upon its underfunded rebellion against the British Empire, the Army's most lethal weapon has been and will continue to be the Soldier.[5] Well trained, highly motivated and firmly disciplined, these Soldiers make the United States the nation with the strongest military power in history. Even though the country has been blessed with these dedicated men and women for more than two centuries, the CMIB has also made

Figure 1. Girls loading point-detonating fuses for high-explosive shells in the body-machining department of a loading plant (circa 1918).[6]

Figure 2. Mark V fuse assembly (circa 1918).[7]

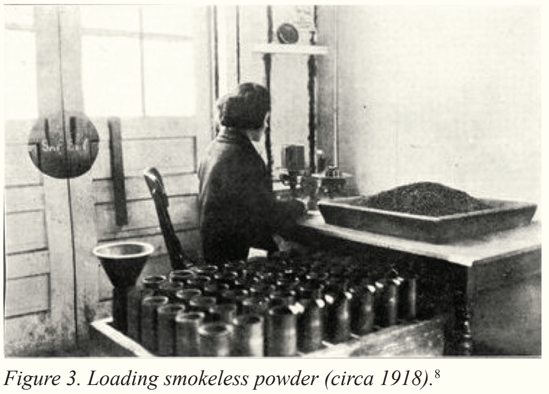


Figure 3. Loading smokeless powder (circa 1918).[8]

critical contributions to this effort. Without this base, the world we recognize today would have been vastly different.

American Revolution to World War I

A chronic problem Soldiers struggled with throughout most of the American Revolution was the shortage of munitions from its decentralized procurement process.[9] Originally, the Continental Congress resolved that its Soldiers were "to find their own arms and cloaths [*sic*]," leaving the supply of munitions to the individual procurement by the Soldiers or the colonies they supported, not by some central ordnance branch. Less than a month after the Army's formation, George Washington wrote to Congress expressing his dire concerns of being "much embarrassed for Want of a Military Chest."[10] Later, he further lamented that "the virtue, spirit, and union of the provinces leave them nothing to fear, but the want of ammunition."[11]

Nearly all of the shots and shells fired but only a meager 10 percent of the gunpowder used during this war were locally produced.[12] The United States was in the midst of a serious economic crisis, with a huge debt. This crisis required difficult decisions about what to procure and led to discussions about permanent establishments of national magazines and arsenals, but ultimately bypassed them in favor of those items deemed essential to immediate existence.[13] The effective establishment of an American CMIB had to wait another day.

When the Civil War began, the CMIB had grown slightly, providing the Army with some of its munitions requirements. It still relied upon several big munitions contractors, who provided all of the artillery, all of the gunpowder and many of the small arms procured during the war. Over a dozen provided munitions, many now defunct, such as Herman Boker & Company, Starr Arms Company, Spencer Arms Company and Eli Whitney Arms Company.[14] Although the government arsenals provided carriages, caissons and accoutrements, private industry provided all of the gunpowder.[15] This war strained the nation as the Army grew from 16,000 regulars in 1861 to more than one million in 1865, creating immense challenges in supplying munitions and requiring international support.[16]

During the first few years of World War I, European nations modernized weapons with machine guns, tanks, airplanes and larger artillery, leaving the American CMIB unable to supply munitions to these new weapon systems.[17] Manufacturing problems, such as tooling delays, labor shortages and inadequate experience forced the government to rely upon foreign firms for most of its munitions requirements.[18] Still, the United States was able to expand its capacity from six government arsenals and two private firms in 1914 to about 20 arsenals and nearly 8,000 ordnance-related manufacturing plants three years later.[19] Munitions requirements, being much higher than previous wars, plagued the military. In 1863, during the three days of the Battle of Gettysburg, Union Soldiers went through over 30,000 artillery rounds. This was small when compared to the four days during the Battle of St. Mihiel in 1918 when American Soldiers expended more than one million rounds.[20] Further, Civil War small arms daily expenditure was four per Union Soldier, again small when compared to the 30 per American Soldier during World War I.[21]

Soon after the war, munitions production lines were abandoned, quickly becoming dilapidated and nearly unusable.[22] Further, despite the large supplies of munitions within the American pipeline on the date of the Armistice in 1918, the nearly two dozen storage depots that existed then soon shrank to 16—seven munitions, two reserve and seven general supply depots.[23]

World War II

A major obstacle during World War II involved the resurrection of a virtually broken CMIB, one that swiftly enlarged its capabilities to unprecedented historic levels. Prior to the war, there were only two government and two private plants that made smokeless powder, along with six ordnance manufacturing arsenals, all capable of providing no more than 5 percent of the war's required munitions.[24] Further compounding the situation was the lack of a peacetime munitions industry, forcing the military to develop the capabilities of commercial manufacturing plants and training its production personnel on its own.[25] Clearly, the Army was not ready to fight this war at its onset.

Deterioration of government facilities resulted from negligible construction during the lean years of the 1920s and 1930s, as many buildings and roads became dilapidated while production equipment became antiquated and obsolete.[26] Because of the worldwide economic depression of the 1930s, military planners considered excess capacity munitions facilities as war reserve, further justifying their decisions to reduce construction requirements.[27] Fortunately, the military had maintained some technical knowledge in these government-owned, government-operated (GOGO) munitions installations, maintaining capabilities to instruct private industry on how to manufacture munitions, while simultaenously serving as the nucleus of the production effort for the wartime effort.[28]

The wartime demands forced the United States to construct nearly 60 manufacturing plants—25 for loading, 21 for producing explosives and smokeless powder and 12 for producing chemical components of explosives—all operating under private contractors.[29] There were different types of munitions plants: ones that produced smokeless powder and other explosive chemicals such as Trinitrotoluene (TNT) and Royal Demolition eXplosive (RDX); ones called Load, Assemble and Pack (LAP) plants that assembled the final rounds and packed them for shipment; and other plants that manufactured metal parts, such as shell bodies and cartridge cases.[30]

To minimize risks associated with enemy attacks and accidental detonations, most of the newly-constructed facilities were built in rural areas, far from large populations. Further, large land requirements were needed to construct production lines that were kept widely separated from one another to prevent the spread of an explosion from one line to another.[31] Because of the explosive hazards involved, the government owned nearly all of the munitions plants.

Choosing not to operate the huge complex of munition plants themselves, the Army opted to use workers from private firms. In a new, unprecedented arrangement, through cost-plus fixed-fee contracts, private firms ran these government-owned, contractor-operated (GOCO) munitions plants.[32] With GOCOs designed as military installations, a small military staff, augmented with civilian government employees, served at each plant as the liaison with the contractors. Augmenting these GOCO plants were contractor-owned, contractor-operated (COCO) facilities that manufactured inert components used to make munitions. For instance, a locomotive company, a steam shovel company and a railway passenger cars manufacturer made carriages for the 155mm rounds.[33] At its wartime peak, there were more than 2,400 prime contractors and 20,000 subcontractors producing munitions.

Labor shortages of personnel with industrial experience impeded munitions production.[34] By February 1943, the Ordnance Department employed a large workforce of civilian employees, peaking at more than a quarter of a million, a size that only a few private industries were able to surpass.[35] Female munitions workers were critical to this effort, as their proportion jumped from over 10 percent during the summer of 1940 to 30 percent two years later.[36]

Besides labor, critical resource shortages prompted innovative solutions. The scarcity of brass prompted production of cartridge cases with steel, while sulfite wood pulp replaced the limited supply of cotton linters. Moreover, cardboard containers replaced tin for packaging munitions.[37] Further, munitions manufacturing plants depended upon industrial chemical firms and oil refining companies for auxiliary chemicals such as anhydrous ammonia, toluene, oleum and ammonium picrate.[38]

To the consternation of the Army in the postwar years, its dwindling demand generated a huge stockpile. The government attempted to sell its sprawling network of Army Ammunition Plants (AAPs) to its operating contractors, who declined as these plants would not support their civilian production efforts. Moreover, they found it difficult, if not impossible, to convert munitions manufacturing equipment to peacetime uses, notwithstanding the required chemical decontamination of the existing explosive residue. Even the land, located in rural areas far from populated and industrial areas, made ownership unappealing to investors.[39]

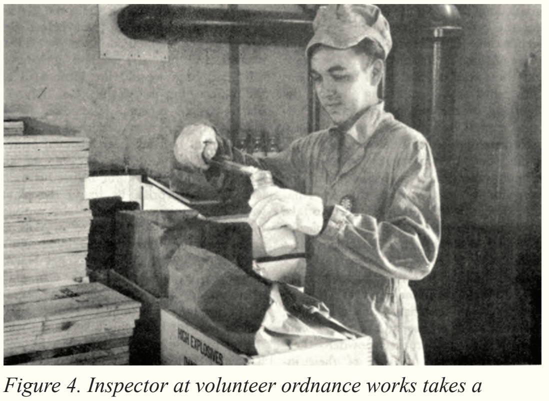


Figure 4. Inspector at volunteer ordnance works takes a sample of Trinitrotoluene (TNT) for testing at an ordnance laboratory (circa 1943).[40]

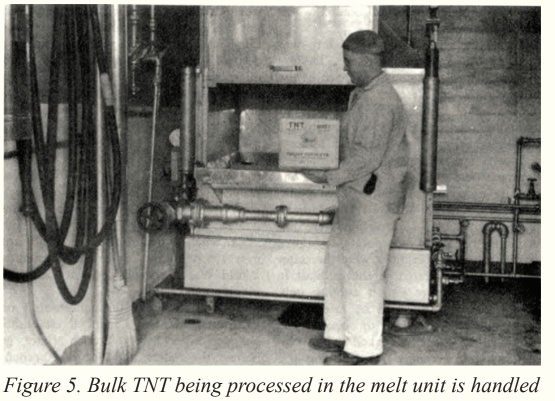


Figure 5. Bulk TNT being processed in the melt unit is handled by a workman wearing non-sparking safety shoes made without nails (circa 1943).[41]

Figure 6. Workmen pouring molten TNT into 155mm shells at the Charleston Ordnance Depot, October 1941.[42]

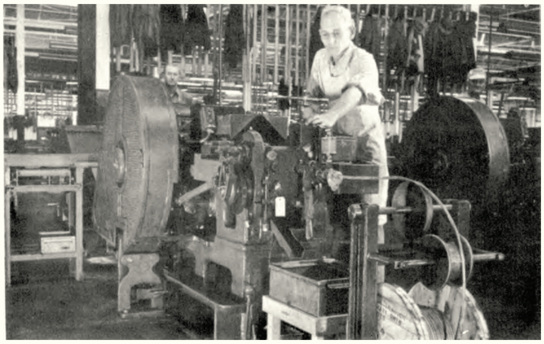


Figure 7. Lead slugs for .45-caliber bullets being cut from a reel of lead wire (circa 1943).[43]

Cold War

Throughout their history, government facilities have lacked the capacity to meet increased wartime demands, especially due to downsizing once armed conflicts have ended.[45] Following World War II, the United States began developing a permanent defense industrial base centered on defense companies, supporting the creation of an international system with a strong centralized American power to prevent future global wars.[46] Accelerating this effort were the United States–Soviet nuclear arms race and the North Korean invasion of South Korea.[47]

Figure 8. .50-caliber machine gun munitions in fabric belts, being arranged for crating in an ordnance arsenal (circa 1943).[44]

Sadly, having been abandoned for five years with virtually no maintenance funding, America's nearly 60 munitions plants were in poor condition, costing more than $600 million to refurbish and reactivate back into service, taking almost two years to accomplish.[48] Congressional funding contributed to delays in reactivating the plants following entry into the Korean conflict. Shortages of machine tools, special-purpose equipment and materials further hampered production. These all made it perfectly clear that the United States was unable to support munitions needs during the initial few years of armed conflicts. Again, the Army was not ready to fight at the onset of a war.

Changes were needed. By 1958, government facilities produced less than 10 percent of all the Army's ordnance, a sharp decline from before World War II when it was producing almost all of its munitions needs.[49] As portrayed in table 1, the defense firms became larger. Additionally, these companies recognized that non-defense markets provided better financial rewards, inspiring them to merge into larger multi-billion dollar defense firms. U.S. governmental bureaucracies sustained these economic giants by making it very cumbersome to work with its agencies and by making future workload predictions risky. As a result, other companies were discouraged from entering the market.[50]

Table 1

Defense Firms[51]

Date	Military Contractors	Percentage of Contracts
1945	Top 100 Top 25	67% 47%
1959	Top 100 Top 25	82% 60%

An obvious sign of the manufacturing decline had been the steady closures of AAPs, their factory whistles permanently falling silent. In 1957, only 19 of the CMIB's 74 plants were operational, with just a quarter of its production lines in operations. A year later, the Army determined that 17 of its inactive plants were in excess and made plans to dispose of them.[52] A few years after that, it had disposed of another 19 plants, this time presuming and perhaps hoping that nuclear warfare would reduce conventional munitions requirements.[53] Once again, this strategy of reducing the CMIB dangerously weakened the Army's ability to fight its next war.

During the initial buildup for the Vietnam War in 1965, about half of the 25 munitions plants were operational; all but one were operational three years later. The process to reactivate munitions plants was much better—it took only three months to restart a TNT plant that then reached full production in eight months, as opposed to eight months restarting one in 1950 and reaching full production rates in 20 months.[54] By 1969, the peak production year, the GOCO plants had nearly 150 lines operational and employed more than 120,000 workers. Yet, the war had revealed some alarming deficiencies. The manufacturing processes had hardly improved, if at all, since the Korean conflict. In many of the small arms munitions plants, the machines were from World War II and still used technology from World War I. Further, the assembly line layouts caused inefficient transport of components within the production areas.[55]

During the 1970s, efforts were made to upgrade government-owned facilities. The capabilities of the defense industrial base declined, mostly from disposal of government facilities.[56] However, in an effort to eliminate duplicate munitions plants and depots throughout the military, the Army became the single manager for conventional ammunition (SMCA), assuming responsibility for the storage, management and disposal of wholesale inventories of munitions and explosives for all of the military services.[57] The government tried to improve the CMIB though an organizational change; meanwhile, they neglected the facilities.

Desert Storm and the War on Terrorism

In support of Operation Desert Storm (ODS), 13 of the 14 AAPs supplied munitions. To meet the demands, the GOGO plants—specifically McAlester Army Ammunition Plant, Pine Bluff Arsenal (PBA) and Crane Army Ammunition Activity (CAAA)—had to accelerate production efforts. McAlester hired 200 temporary workers.[58] Pine Bluff had to quickly reconstitute its production lines.[59] And Crane accelerated shipments of munitions, with many of its prodigious, bone-weary workers putting in 16- to 18-hour shifts, some even working 25 hours straight.[60]

Despite commercial defense firms successfully meeting the ODS munitions demands, managerial directions had changed since the 1970s when these firms had begun adopting the management practices of commercial firms. Increasingly, the top commercial munitions managers began concentrating more on bottom-line financial returns for their shareholders, increasing their share of the market and eliminating competition.[61] This led them to incorporate new business techniques to reduce costs and improve performance, such as strategic supplier management, advanced inventory management, activity-based costing and continuous improvement.[62] These changes not only reduced the number of available firms and changed their relationships with the government; they also made it harder for non-defense firms to compete for defense work.[63] As listed in table 2, most of the revenue source for the major munitions firms came from defense work. Solidifying their influence in the conventional munitions market, many of these firms came together in 1993 to form the Munitions Industrial Base Task Force, a nonprofit association.[64] With a common goal to educate individuals within

Table 2

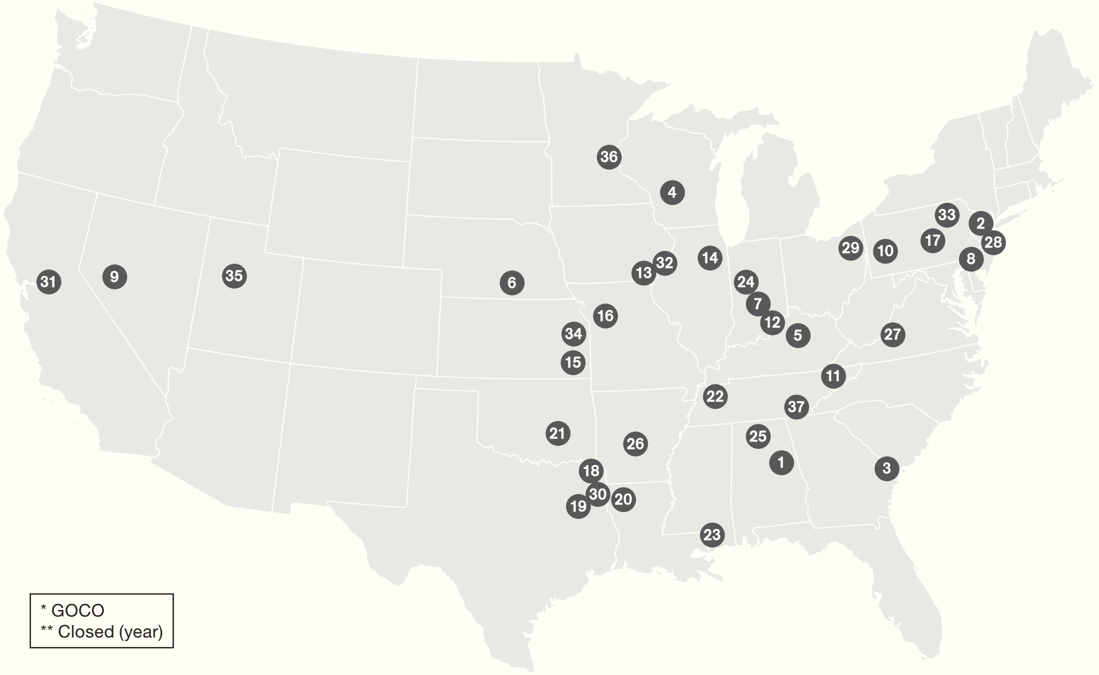
Major Munitions Firms

Firm	Country	FY 2013 Defense Revenue	% Defense Revenue
BAE Systems[65]	United Kingdom	$28 billion	94%
General Dynamics[66]	United States	$18.8 billion	60%
Alliant Techsystems, Inc. (ATK)[67]	United States	$2.5 billion	53%
Chemring Group[68]	United Kingdom	$0.9 billion	>95%
Esterline[69]	United States	$0.7 billion	35%
Day & Zimmermann[70]	United States	$0.5 billion	24%

Figure 9

Map of Key Munitions Facilities

GOGO, GOCO and year closed



1. Anniston Munitions Center *
2. ARDEC
3. Augusta Arsenal ('55) **
4. Badger AAP ('75) **
5. Blue Grass Army Depot
6. Cornhusker AAP ('74) **
7. Crane AAA
8. Delaware Ordnance Depot ('58) **
9. Hawthorne Depot *
10. Hays AAP ('71) **
11. Holston AAP *
12. Indiana AAP ('45) **
13. Iowa AAP *
14. Joliet AAP ('90) **
15. Kansas AAP ('09) **
16. Lake City AAP *
17. Letterkenny Munitions Center
18. Lone Star AAP ('09) **
19. Longhorn AAP ('97) **
20. Louisiana AAP ('96) **
21. McAlester AAP
22. Milan AAP *
23. Mississippi AAP ('09) **
24. Newport AAP ('68) **
25. Phosphate Development Works ('57) **
26. Pine Bluff Arsenal
27. Radford AAP *
28. Raritan AAP ('61) **
29. Ravenna AAP ('92) **
30. Red River Munitions Center ('07) **
31. Riverbank AAP ('81) **
32. Rock Island Arsenal
33. Scranton AAP *
34. Sunflower AAP ('71) **
35. Toole Army Depot
36. Twin Cities AAP ('05) **
37. Volunteer AAP ('69) **

the government and to recommend actions to preserve key capabilities, this task force meets monthly to develop strategies and initiatives for munitions base preservation and readiness.

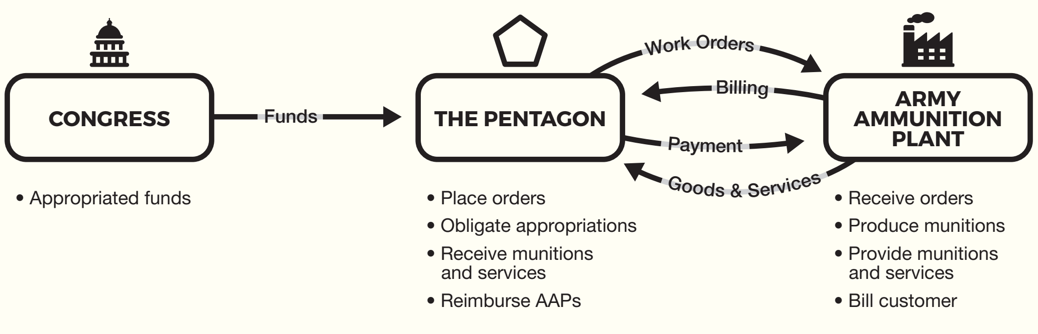
This brings us back to the importance of the CMIB. Today, as illustrated in figure 9, the CMIB is a combination of GOGO, GOCO and COCO facilities for meeting military requirements during both peacetime and wartime, while attempting to ensure that munitions are available, reliable, sustainable and affordable.[71] Although manufacturing is not a military core capability, the Army must possess the capability to be a smart purchaser, which it tries to do by maintaining an in-house expertise of engineering and production specialists. Further, since the Army cannot compete directly with the private sector, its GOGO production capacity is maintained primarily for those areas in which the private sector is unwilling or unable to establish required munitions manufacturing capabilities.[72] Given such trends—and with Army readiness at risk—munitions managers are justified in asking for strategic clarity.

Financial Operations

Government facilities responsible for producing munitions use a revolving fund instead of operating directly from appropriated funds. Specifically, they manage their money through the Army Working Capital Fund (AWCF), under the provisions of Title 10 U.S. Code, § 2208. Unlike profit-oriented commercial businesses, the goal of this fund is to break even by returning any gains to appropriated funded customers through future lower rates or by collecting any losses through higher rates.[73] Through customer relationships, these GOGO facilities stabilize their fund prices during the year of execution to protect customers from unforeseen fluctuations. The Department of Defense (DoD) Financial Management Regulation governs the operations of AWCF facilities, as it does with other Defense Working Capital Fund (DWCF) organizations.[74] As shown in figure 10, customers receive appropriated funds from Congress, place orders with AWCF units and obligate the appropriations when accepted. Unlike the common practice of commercial businesses, no work begins until after the AWCF units receive the funds. However, the AWCF units recognize revenue with payments from the funds after the work has been performed.[75]

Figure 10

Working Capital Fund Process for AAPs



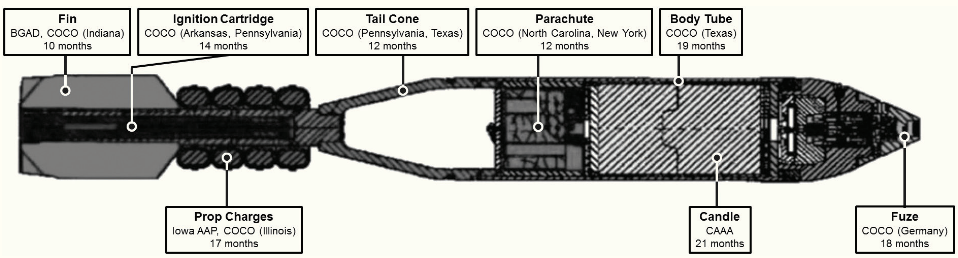
These revolving funds began as service-owned revolving funds, originally known as stock and industrial funds, which Congress eventually combined into one fund (the Defense Business Operations Fund) on 1 October 1991.[76] Regrettably, the assumption of operating in a normal free-market environment is the central fallacy in the policies driving the DWCF. Instead, these policies failed to take into account the bureaucratic nature of the defense industry.[77] Despite numerous reform attempts, the DWCF environment lacks effective competition, creative innovation and classic free-market characteristics.[78]

Highlighting the complexities of long-term munitions production in 2007 was the Marine Corps' need for slightly more than 50,000 visual light 81mm mortar rounds, consisting of 12 key components and including fins, tail cones, fuses and pyrotechnic candles. PBA received about $7 million to load, assemble and pack the rounds. In addition to awarding several contracts to vendors (including a German firm) to procure needed components, the Army customers issued orders to CAAA to produce the candles for these mortar rounds. Because PBA and CAAA could not start their work until they received the required components, as illustrated in figure 11, they had to carry over the funds more than a year into 2009.[79]

Figure 11

Lead Times and Sources to Obtain Components

81mm Visual Light Round



The capabilities of commercial suppliers also impacted carryover funds. In 2006, PBA received two orders to produce about 40,000 155mm white phosphorous smoke rounds, with plans to deliver 6,000 about 18 months later. However, they were unable to obtain reliable burster charges, a major component of the round. After terminating two contracts with commercial firms for their failure to meet test requirements, the Army was forced to develop the manufacturing capabilities itself for these components, choosing CAAA for this effort.[80]

The initial challenge was to adapt the prototype equipment to CAAA facilities that received the primary pieces of equipment such as the kettle. However, the equipment was not modular and was intertwined with all their other processes. Therefore, CAAA had to develop all the electrical controls, hot water controls and finishing equipment to produce these items. Furthermore, during the installation and control design process, alternate pouring methods were developed. After more than two years of trials, CAAA optimized the system, resulting in a less than 1 percent rejection rate. Previous rejection rates had exceeded 50 percent. PBA provided a significantly higher-quality smoke projectile.[81] Once again, a GOGO facility, not a commercial firm, demonstrated its crucial link between the Soldier and the required supply of munitions.

Munitions Safety

Safety is a critical component of munitions manufacturing, having a tremendous impact not only on financial performance but also on the capability to provide munitions when needed. As expected, working around munitions is a hazardous activity, as listed in table 3. In its first major engagement of the Seminole Wars in 1816, the U.S. military attacked Fort Apalachicola, a former British fort defended by Native Americans and fugitive slaves. Its warships bombed the fort, setting its powder magazine on fire and causing an explosion that killed more than 270 defenders.[82] During the Civil War in 1862, at the Allegheny Arsenal near Pittsburgh, Pennsylvania, powder carelessly left on the building floors caused an explosion, killing 78 people. Most of the casualties were young girls, some of them not much older than 10 years of age.[83] In 1865, shortly after the Civil War, an ordnance depot exploded in Mobile, Alabama, killing approximately 300 people and destroying the northern part of the town.[84]

Table 3

Key Historical Munitions Explosions

Date	Locations	Results
27 July 1816	Fort Apalachicola, Florida	More than 270 killed
17 September 1862	Allegheny Arsenal, Pennsylvania	78 killed
25 May 1865	Mobile, Alabama	~300 killed
11 January 1917	Canadian Car, Kingsland, New Jersey	Plant destroyed; several people missing
10 April 1917	Eddystone Ammo, Philadelphia, Pennsylvania	133 killed
4–6 October 1918	T.A. Gillespie Co., Morgan, New Jersey	More than 100 killed; more than 100 injured
1 March 1924	Nixon Nitration Works, Nixon, New Jersey	18 killed; two missing; more than 100 injured
10 July 1926	Lake Denmark Powder Depot, New Jersey	21 killed; more than 200 injured; Department of Defense Explosives Safety Board formed
5 June 1942	Elwood Ordnance Plant, Illinois	48 killed; 41 injured
17 July 1944	Port Chicago, California	320 killed; 390 injured
16 April 1947	Texas City, Texas	581 killed; hundreds injured

Colonel Beverly Dunn, who developed ammonium picrate (also known as Explosive D) served as the chief inspector of the Bureau of Transportation Explosive.[85] In his position, he highlighted the hazardous concerns of storing and transporting munitions, prompting the Association of Manufacturers of Powder and High Explosives to appoint a committee to investigate explosive accidents worldwide.[86] After assessing the damages from 122 explosive accidents between the years 1864 and 1914, this committee developed the American Tables of Distances. Published in 1915, these tables contained the minimum permissible distance allowed between inhabited buildings and explosive quantities up to one million pounds.[87]

Still, accidents continued into World War I. In 1917, the Canadian Car and Foundry Company in Kingsland, New Jersey, exploded while manufacturing munitions. As seen in figure 12, the plant was destroyed and several people were reported missing and presumed killed.[88] A few months later in the same year, an explosion took the lives of 133 people, mostly girls and young women, at the Eddystone munitions plant near Philadelphia. Although the exact cause of this explosion remains unknown, some theories suggested that it was a Russian saboteur. Naturally, this raised concerns about the security of munitions plants.[89] The following year, an explosion destroyed a production building at the T.A. Gillespie Company in Morgan, New Jersey, killing everyone inside. Because of inadequate fire protection, faulty building construction, unavailability of water and the short distances between the buildings, most of the damage happened after the explosion itself. Besides the destruction of the plant and the loss of 12 million pounds of explosives, the nearby town suffered damages severe enough that its residents were forced to evacuate.[90]

In 1924, an explosion struck the Nixon Nitration Works near New Brunswick, New Jersey, a site that produced and stored explosives used for munitions, such as ammonium nitrate and TNT. The resulting fires spread to other buildings, completely destroying 40 of them, killing 18 people and injuring more than 100 more.[91] In 1926, lightning struck one of Lake Denmark's munitions magazines, causing it to explode several minutes later. Embers from the explosion detonated munitions in other magazines, causing a cascading effect. In the end, 19 people died and all structures within a half mile of the lightning strike were annihilated, along with buildings more than a mile away receiving some level of damage, including the adjacent Army's Picatinny Arsenal.[92] The biggest concern was that all safety protocols had been followed. This event became the impetus for Congress in establishing the Department of Defense Explosives Safety Board, originally called the Armed Forces Explosives Safety Board. Subsequent arsenals and munitions storage facilities were placed in low-population locations.[93]

Figure 12. Canadian Car and Foundry Company's Plant, Kingsland, New Jersey, after the fire and explosions (Photo 1917 International Film Service, Inc.).

During World War II, with its extensive level of munitions production, there were 667 incidents involving explosions and fire, causing the death of over 300 people.[94] The locations with the highest number of fatalities are listed in table 4. In 1942, the most deadly explosion during production was at the Elwood Ordnance Plant, Illinois, involving a building and three railcars and resulting in the death of 48 and injuries to nearly 70.[95] At the Iowa Ordnance Plant, a melt tower detonated in 1941, killing 13. At the same facility, another melt tower detonated the following year, killing 22 this time.[96] Exceeding the production design rates and surpassing the safe storage limits, the Triumph Explosives Company in Elkton, Maryland, had a granulator detonate in 1943—it spread to four buildings and killed 15 people. In the Naval Ammunition Depot at McAlester, Oklahoma, in 1944, while a magazine crew was loading Torpex bombs from a trailer into an igloo magazine, a detonation in the magazine propagated to the trailer, killing all 11 crewmembers.

Table 4

Most Fatal World War II Munitions Explosions

Location	Number of Incidents	Fatalities
Elwood Ordnance Plant	4	53
Iowa Ordnance Plant	15	36
Naval Ammunition Depot Hastings	3	26
Triumph Explosives Company	41	23
King Powder Company	17	12
Portage Ordnance Plant	1	11
Naval Ammunition Depot McAlester	1	11
Cornhusker Ordnance Plant	2	7
Louisiana Ordnance Plant	16	7
Remington Arms Private Plant	6	7
Radford Ordnance Plant	26	7

Transporting munitions was also a hazardous activity, sometimes even fatal. During World War II, railway and trucking firms moved nearly 10 million tons of munitions, resulting in 32 explosive incidents. Half of these were on rail lines, with two fatalities, while truck movements resulted in 11 fatalities.[97] Without doubt, the deadliest munitions explosion during this

Figure 13. Aftermath of the 10 July 1926 explosion at the U.S. Naval Ammunition Depot at Lake Denmark. Courtesy of the National Archives, photo no. 71-LD-121.

Figure 14. Aftermath of the 17 July 1944 explosion at the Port Chicago Naval Magazine. (National Park Service Digital Image Archives).

war happened at the Port Chicago Naval Magazine in California. One evening in 1944, residents of San Francisco's East Bay area were jolted by a massive explosion that lit up the night sky. Three hundred and twenty men were killed when the munitions ship they were loading mysteriously exploded.[98] Less than three years later, in 1947, an even more fatal explosion occurred with the detonation of over 2,000 tons of ammonium nitrate, in the Port of Texas City, killing nearly 600.[99] The exact cause of the fire sparking the initial detonation was never determined.

Figure 15. Parking lot a quarter of a mile away from the Texas City explosion. Courtesy of Special Collections, University of Houston Libraries (18 April 1947).

To minimize future accidents, the Army established safety standards for munitions, setting explosive limits in structures based on net explosive weight, setting handling precautions using Quantity Distance tables and setting controls at the installations using approved Explosive Safety Site Plans (ESSP).[100] The ESSP described in text and graphics the relationship between a proposed potential explosion site, personnel and facilities, along with describing the required auxiliary equipment.[101] To ensure compliance, the Army used trained professionals within the Quality Assurance Specialist (Ammunition Surveillance) Program to inspect and monitor munitions-related operations.[102] As another critical example of why the government must maintain its munitions competencies for Army readiness, adherence to a robust explosives safety program reduces risks of death, injury and property destruction.[103]

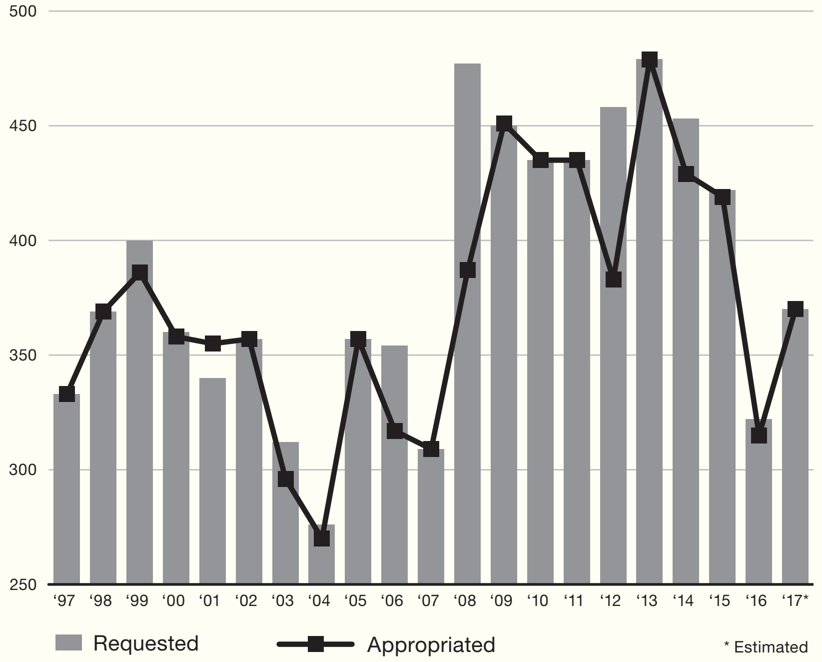
Readiness Challenges

Storage

Munitions storage, care of stocks in storage (COSIS), surveillance, distribution and demilitarization are important for readiness.[104] A significant challenge within the CMIB involved quantities and age of munitions. There was reason for concern that in the 1990s, nearly 30 percent of the almost 3,000 types of munitions were short of required quantities, determined by each of the military services, yet were manageable because of substitute items and planned procurements.[105] However, the largest quantity storage challenge involved excess and unusable

Figure 16

Ammunition Management Funding



munitions, which in the mid-1990s was almost 40 percent of the nearly $80 billion stockpile. This equated to three million tons stored in nine depots, two plants and one arsenal, requiring nearly 40 million square feet of storage space.[106] For some munitions types, the CMIB stored more than 50 times the required quantities. Sustaining more munitions than needed wastes operation and maintenance (OMA) funds provided for COSIS and surveillance. As illustrated in figure 16 for OMA funds provided by fiscal year, money available for this appears to fluctuate from $350 million to $450 million each year for conventional munitions management.[107] Yet this may not be sufficient for future needs if funding continues to be wasted by the storage of unnecessary munitions.

As outlined in table 5, nearly one quarter of the stored munitions were more than 25 years old when the War on Terrorism began to deplete the stock.[108] Although many of the old munitions were usable, commanders preferred to use newer ones, causing munitions to age and retain storage space, increasing the amount of excess munitions. Controlling those storage facilities, the SMCA faced two problems when trying to dispose of excess munitions. First, the SMCA was obligated to store the munitions until the other military services relinquished ownership of them, which they had no incentive to do as the

Table 5

Storage Munitions Age

as of March 1995

Age	Lots	Percentage
0–5 years	40,688	26%
5–10 years	30,150	19%
10–15 years	18,474	12%
15–20 years	14,986	9%
20–25 years	15,130	10%
25–30 years	16,587	10%
30+ years	22,453	14%
Total	**158,487**	**100%**

SMCA bore all financial and operational responsibility for storage. Second, the disposal of excess munitions was both time-consuming and expensive, also coming from SMCA resources.[109] However, in 2008, the Defense Acquisition Executive developed the policy of "Design for Demilitarization" that required procurement officials to incorporate demilitarization costs into the lifecycle costs, reducing the burden of the SMCA to bear full costs for disposal.[110]

Although not currently managed within the CMIB, the previous practice of disposing of munitions through water dumping affected the safety of beachgoers each year. Until 1970, perhaps believing the practice to be a permanent disposal method, DoD dumped excess and unusable munitions in the waters off of the continental shores, something Congress eventually prohibited with the Marine Protection, Research and Sanctuaries Act of 1972. With this act, DoD developed an inventory of sea disposal sites, which is updated as new information becomes available.[111] Today, World War II munitions frequently manage to wash up on U.S. beaches, forcing people to evacuate until they are safely removed. A Texas A&M oceanographic study in 2012 documented seven main dump sites in the Gulf of Mexico, with an estimated 30 million pounds of munitions.[112]

Recommendation 1: Conduct a comprehensive strategic review of conventional munitions, standardizing the items with joint capabilities towards elimination of single-service requirements.

Recommendation 2: Demilitarize those items no longer needed and maintain those that are needed.

Facilities

Based upon multiple studies conducted in the 1990s, much of the equipment in the CMIB government facilities was old, obsolete and expensive to operate, indicating capability concerns for sustaining the quality and quantity of munitions required for a prolonged national emergency.[113] Maintaining and modernizing equipment was expensive, especially since manufacturing is typically a commercial function and not an inherently governmental function; perhaps this explains why the government spends nearly all of its munitions dollars with commercial firms.[114] A large think tank conducted an extensive review of the CMIB from 1999 to 2002 and criticized the Army's historical imperative to own this base.[115] Although their recommendations were considered, the munitions community rejected them, preferring to comply with the policy to maintain a sufficient stockpile to support two near-simultaneous major regional conflicts, with replenishments through increased production at organic facilities and contracts to qualified commercial firms.[116]

Considering these studies, along with the Department of Energy's 1997 recommendation that the Army should create a flexible CMIB, Congress funded a research initiative called the Totally Integrated Munitions Enterprise (TIME) program. Unfortunately, this was a congressionally-directed initiative, known as a plus-up, rather than coming from the defense budget process. Thus, ownership, accountability and funding for the TIME program was outside the normal DoD chain of command, with limited, involvement from the CMIB sites.[117] Predictably, this program did not survive very long.

Because it was a research effort, the National Academies evaluated TIME and reported its results in 2002. Many of its findings suggested a need for a widespread overhaul of the GOGO and GOCO facilities, identifying obsolete equipment, weak quality controls and outdated processes.[118] Yet, even though they may not have fully understood the operational aspects of the CMIB at the shop-floor level, they cautioned that modernizing these facilities was a complex effort that involved not only technical issues but also political and economic factors.[119] Still, information obtained from the TIME program provided a useful roadmap for potential facilities modernization, from improving equipment controllers with integration of business processes to effective supply chain management communications from suppliers to customers.

Although many experts warned about the capabilities of the decaying CMIB facilities, its equipment and processes met the demanding requirements of the warfighters expending munitions in the Iraq and Afghanistan theaters for more than a decade (America's longest war). That said, inadequate funding, fluctuations in buys and lack of long-term commitment had not fostered significant investment in modernizing facilities.[120] Now, in 2017, nearly 22 percent of all government defense facilities are in poor or failed condition, making it of utmost importance to Army readiness that this trend be reversed.[121]

Even without sequestration, force reductions or hiring freezes, future funding cutbacks in the CMIB are likely based upon historical patterns, making key infrastructure improvements unlikely. Expecting only munitions procurement dollars for facility improvements is not enough. Why? Because this is the same funding stream that is used to support research, development and acquisition expenses.[122]

In the late 1990s, the AAPs were operating at around 20 percent capacity utilization, with an annual cost of underutilized capacity at nearly $250 million (2015 dollars).[123] Although much of this capacity was used during the wars in Afghanistan and Iraq, one of these nine plants had closed—Lone Star in 2009—reducing the available storage and production area by more than six million square feet. In addition to this, sequestration, fiscal uncertainty and reduced requirements made it more important to identify and maintain critical CMIB with the properly-sized capacity to meet future requirements.[124]

In 2000, Congress initiated the Arsenal Support Program Initiative, a demonstration program to help maintain visibility of the Army's manufacturing capabilities. This program was supposed to allow commercial firms to use skilled government workers and to encourage these firms to use Army facilities for commercial purposes, while spreading innovative business practices throughout the Army. Furthermore, this was supposed to reduce government ownership costs while reducing procurement costs for munitions.[125] However, after a decade, not much came out of this initiative, with the Army only identifying nearly one million square feet of space at the Rock Island and Watervliet Arsenals. The only munitions facility in this program was PBA, which participated minimally through leasing of railyard space.[126] All the same, the Army works closely with commercial firms through the Public Private Partnership (PPP) in a collaborative effort to reduce costs, with nearly 300 such partnerships in 2013 that generated more than $200 million in revenue for the organic industrial base.[127]

Initiated in 1999 to replace two aging material management systems that had been used for more than three decades to manage inventory and manufacturing operations, the Logistics Modernization Program (LMP) was intended to improve business processes and increase operational efficiencies. The Army expected improved budget forecasts, better resource allocation, increased production rates, reduced costs and better schedules.[128] However, the CMIB required specific functionality that in turn required an interim solution using SmartChain, an external software application that interfaces with LMP to temporarily track receipts, inventories and shipment of munitions.[129] This lack of functionality is another example that demonstrates that the Army did not consider munitions requirements for improving its material management.

Sadly, implementing a new computer system was not a panacea for CMIB problems. In the end, leaders found more advantages in consolidating technologies and skills that would empower individuals to adapt quickly to changing opportunities, rather than trying to implement outdated decisions made several years ago that would solve non-critical issues.[130] Even the Army's strategic vision for its industrial base, focusing solely on the five areas of modernization, capacity, capital investment, resources alignment and PPP promotion, may not be enough.[131] Modernization is more than software updates and facilities upgrades; it should include modern practices and procedures. But nothing describes how these modernization efforts are prioritized and who makes that determination. This PPP effort encourages CMIB government facilities to compete for workload alongside commercial firms. These commercial companies, with large indirect staffs, will have the advantage of competing for contracts over GOGO units.

Despite the importance of the CMIB, the Army has not yet developed policies to protect its capabilities. With about 95 percent of munitions manufacturing going to commercial firms, the GOGO workload is left to the whim of acquisition managers who are more interested in cost, schedule and performance.[132] Using the same business model for depot-level repair that mandates a 50 percent split between government and industry, some have proposed that the government should control at least a third of its munitions production workload.[133] Converting the GOCO facilities into GOGO facilities could do just that—provide the government with managerial control over one-third of the munitions production capabilities.

Recommendation 3: Decide which part of the CMIB should be saved, which part should be eliminated and the correct ratio of government to private producers.[134]

Recommendation 4: Set aside a minimum percentage of munitions contracts to the GOGO sites and provide their products as government-furnished material to commercial companies instead of forcing these sites to spend precious labor hours attempting to win work, often an exercise in futility.[135]

Workforce

Shown in figure 17 (which contains both depot maintenance and munitions), military staffing of nearly 450 in the 1990s had dropped to under 50 by 2001. During the wars in the 2000s, the civilian staffing peaked at nearly 27,000 in 2010 and had dropped by more than 20 percent into 2017 to under 20,000.[136] Should this workforce shrink any further? On closer examination, the skills involved in munitions-related production generally cannot be adapted to commercial application, nor can existing commercial production experience be converted to munitions productions, which makes it critical that munitions skills be preserved.[137]

Although the munitions plants have strategic plans that provide mission statements, vision statements and goals, they tend to conflict with the plans of their higher headquarters. Instead of being coordinated by these headquarters, workforce requirements are established primarily by customers. For more than a decade, challenges affecting munitions plants have been the multiskilling of the workforce and its aging workers. For the CMIB to be competitive, workers

Figure 17

Industrial Operations Workforce

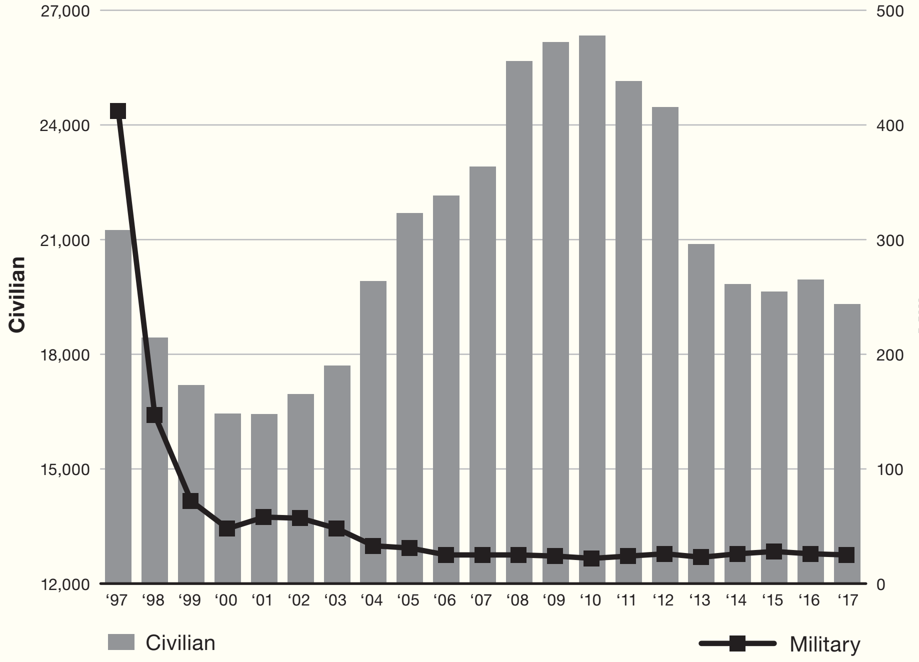


Table 6

Civilian Personnel Eligible to Retire

		FY 2002		FY 2007	FY 2009
Facilities	**Staffing**	**Average Age**	**Eligible**	**Eligible**	**Eligible**
PBA	804	49	11%	43%	63%
CAAA	620	49	29%	49%	60%
MCAAP	1,075	44	21%	30%	48%
Total	**3,655**	**48**	**16%**	**38%**	**51%**

must learn more skills so that production lines become more efficient with flexibilities such that its critical jobs can be performed by fewer people. Not surprisingly, this could require additional compensation for these workers.[138] As depicted in table 6, the number of workers eligible to retire has risen from 16 percent in 2002 to over 50 percent in 2009, despite the fact that the number of federal employees grew by more than 10 percent during this period.[139] Compounding this problem is the lack of local plans to deal with this issue, together with the restrictions for hiring a replacement only after a worker retires, decreasing the ability to retain skills and knowledge from retirees.[140] Given the current era of declining budgets, this is hugely problematic when it comes time to replace these retiring workers, especially in terms of training and hiring costs.

Recommendation 5: Give the GOGO commanders the authority to hire government workers to meet workload requirements and to mitigate anticipated losses through overhires.

Conclusion

The CMIB did not suddenly appear like airborne troops landing on enemy forces far from the front lines, but rather through historical ordeals, many times fatal. Although not perfect, this industrial base has supported the U.S. military successes from initial sovereignty more than two centuries ago to its undisputed global superpower position today. While it was, all things considered, good enough in the past, the question now is whether it will be good enough for future readiness needs. There is a problem but, unfortunately, not a clear or valid solution. In 2012, though, the Army attempted to meet this need by issuing a strategic plan for its organic industrial base as it transitions from a wartime to a peacetime environment.[141] Its vision requires a "modern, cost effective and highly responsive Enterprise that provides and maintains the resources, skills, and maintenance and manufacturing competencies necessary to sustain the lifecycle readiness of warfighting weapon systems . . . worldwide in a reliable and efficient manner while also maintaining the capability to surge as required to meet the demands of future contingency operations."[142] A vision laid out like that sounds simple enough, but it is not; it does not specify which resources are needed and what will be done to sustain them. It is time for strategic clarity.

The CMIB is a critical element for Army readiness, even if it is not fully utilized during long periods of reduced demand. Yet, when the demand increases and becomes an urgent necessity, it must be responsive, dependable and reliable. The United States is faced with a crucial question, the same question that it has had to answer repeatedly for more than two centuries: what can be done to ensure that the CMIB is able to sustain Army readiness, and how can sufficient resources best be dedicated to this effort? The answer to this may very well determine how long the United States will maintain its uncontested military power in the world. With the clock ticking, may we always have the readiness capability to "praise the Lord and pass the ammunition."[143]

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[29] Service, Supply and Procurement Division, *Logistics in World War II*, pp. 96–97; Thomson and Mayo, *The Ordnance Department: Procurement and Supply*, pp. 17, 110–111. In 1940, each district office had hundreds of industrial surveys made during the preceding years, nearly up-to-date, covering major industrial plants that might be converted to munitions production in time of war.

[30] Shipman, *Forging The Sword: Defense Production During the Cold War*, p. 17.

[31] *Ibid.*, pp. 16, 17, 20. Plants were in widely-spaced areas, consisting of administrative, support or production facilities grouped by function. Unlike a civilian industrial plant with facilities housed under one roof whenever possible, the government-owned ammunition plants had separate buildings connected by covered walkways.

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[59] *Ibid*., pp. 45–46. Pine Bluff Arsenal produced and shipped 155mm white phosphorus smoke projectiles to the Persian Gulf and then began production of 60mm white phosphorous mortars and 40mm smoke markers.

[60] *Ibid*., p. 51. Crane delivered 7,546 short tons of ammunition in a mere ten days, as well as loading 66 semi-trucks and 52 railcars in 23 days.

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[67] *Ibid*.

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[73] Department of the Army, *Army Working Capital Fund Fiscal Year 2016 Budget Estimates* (Washington, DC: U.S. Government Printing Office, February 2015), p. 1, http://asafm.army.mil/Documents/OfficeDocuments/Budget/budgetmaterials/fy16/awcf.pdf.

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[81] Scott S. Haraburda and Lara E. Zilafro,"Developing a Continuous Improvement System," *Defense AT&L 41*, vol. 41, no. 1, January/February 2012, pp. 29–32, http://dau.dodlive.mil/2012/01/08/developing-a-continuous-improvement-system.

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[84] Clayton R. Newell and Charles R. Shrader, *Of Duty Well and Faithfully Done: A History of the Regular Army in the Civil War* (Lincoln: University of Nebraska Press, 2001), p. 127; H.K. Thatcher, "Explosion of a Magazine at Mobile, Alabama, dated 29 May 1865" in Gideon Welles' *Report of the Secretary of the Navy* (Washington, DC: U.S. Government Printing Office, 4 December 1865), pp. 388–389.

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[89] Karen Ivory, *Pennsylvania Disasters: True Stories of Tragedy and Survival*, 2nd ed. (Kearney, NE: Morris Book Publishing, 2007), pp. 73–77; Robert F. O'Neill, "The Mystery Lives Where 139 Perished," *The Inquirer*, Philadelphia, PA, 19 April 1992, http://articles.philly.com/1992-04-19/news/26001794_1_shells-munitions-plant-sabotage. This article identifies facts suggesting that the cause might have been a Russian saboteur opposing the Czar, perhaps part of the Bolshevik Revolution.

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[94] Edward P. Moran, Jr., "Explosive Accident Summary: World War II," *25th Explosives Safety Seminar* (Anaheim, CA, 18–20 August 1992), pp.113–131, http://www.dtic.mil/dtic/tr/fulltext/u2/a260984.pdf.

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[97] Moran, "Explosive Accident Summary: World War II."

[98] U.S. National Archives, Pacific Sierra Region, Record Group: 181, 12th Naval District Commandant's Office, General Correspondence Series, 1946, Box: 7/12, Folder A17.25, vol. 8, 19 May 2015, http://www.history.navy.mil/browse-by-topic/disasters-and-phenomena/port-chicago-ca-explosion/online-documents/court-of-inquiry.html.

[99] Bill Minutaglio, *City on Fire: The Explosion that Devastated a Texas Town and Ignited a Historic Legal Battle* (Austin: University of Texas Press, 2014). The death toll was probably higher.

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[101] Department of the Army, *Explosive and Chemical Site Plan Development and Submission*, Army Pamphlet 385-65 (Washington, DC: U.S. Government Printing Office, 20 June 2009), http://www.apd.army.mil/pdffiles/p385_65.pdf.

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[105] GAO, *Defense Ammunition: Significant Problems Left Unattended Will Get Worse*, p. 5.

[106] *Ibid.*, pp. 2–3, 15.

[107] OMA (Operations and Maintenance, Army), Budget Data from the Justification Book for Fiscal Year (FY) 1999–2017 and the Army Green Book for FY 1997–1998, http://asafm.army.mil/Document.aspx?OfficeCode=1200.

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[110] DoD Instruction Number 5160.68, *Single Manager for Conventional Ammunition (SMCA): Responsibilities of the SMCA, the Military Services, and United States Special Operations Command (USSOCOM)*, 29 December 2008, http://www.dtic.mil/whs/directives/corres/pdf/516068p.pdf.

[111] "Chapter 10: Sea Disposal of Military Munitions," *FY 2009: Defense Environmental Programs Annual Report to Congress*, p. 86, http://www.denix.osd.mil/arc/upload/10_FY09DEPARC_Sea_Disposal_DENIX.pdf.

[112] Matthew Diebel, "Sharks? World War II bombs also are a beach peril," *USA Today*, 20 July 2015, http://www.usatoday.com/story/news/2015/07/20/unexploded-bombs-dumped-off-american-coasts---peril--beachgoers/30415739/. See also "Military Ordnance Found on U.S. Shores," *The Journal of ERW and Mine Action*, vol. 17, no. 3, Fall 2013, http://www.jmu.edu/cisr/journal/17.3/briefs/stern.shtml; and "A Real Ticking Time Bomb," *Texas A&M Today*, 3 August 2015, http://today.tamu.edu/2015/08/03/a-real-ticking-time-bomb/.

[113] Committee to Evaluate the Totally Integrated Munitions Enterprise (TIME) Program, *Munitions Manufacturing: A Call for Modernization* (Washington, DC: National Academies Press, 2002), p. 20, http://www.nap.edu/catalog/10351.html; Steven Mullen, "Ammunition Readiness: Current Problems and Future Implications for Army Transformation," AUSA Landpower Essay 02-1, February 2002, https://www.ausa.org/sites/default/files/LPE-02-1-Ammunition-Readiness-Current-Problems-and-Future-Implications-for-Army-Transformation.pdf. The Army is woefully short of required state-of-the-art munitions and the munitions production base is suffering. Funding is marginal. The Army cannot make up preferred munitions shortfalls during a major conflict.

Replenishment is longer than three years for many critical/preferred munitions. The United States essentially has no surge capability.

[114] William M. Hix, Ellen M. Pint, John R. Bondanella, Bruce J. Held, Michael V. Hynes, David E. Johnson, Art Pregler, Mike Stollenwerk and Jerry M. Sollinger, *Managing the Army's Arsenals and Ammunition Plants*, Report RB-3038-A (Santa Monica, CA: RAND Corporation Arroyo Center 2003), http://www.rand.org/content/dam/rand/pubs/research_briefs/2005/RB3038.pdf.

[115] *History of the Ammunition Industrial Base* (Rock Island Arsenal, IL: Joint Munitions Command, December 2010), p. 51, http://www.jmc.army.mil/Docs/History/Ammunition%20Industrial%20Base%20v2%20-%202010%20update.pdf. RAND provided five different options for dealing with the AAPs, rejecting the status quo for a variety of reasons. Their analysis supported privatization as the best option, yet cautioned that privatization could reduce capacity and capability; Hix et al., *Managing the Army's Arsenals and Ammunition Plants*.

[116] Committee to Evaluate the Totally Integrated Munitions Enterprise (TIME) Program, *Munitions Manufacturing: A Call for Modernization*, p. 2.

[117] *Ibid*., p. 13. Within the Army, the TIME program was overseen by TACOM–ARDEC at Picatinny Arsenal in New Jersey.

[118] *Ibid*., pp. 3–4.

[119] They never visited any plants and do not cite having received any briefings from the plant operators. All information appears to have come from the Armament Research, Development and Engineering Center and engineering channels, although they may have received briefings from some civilian defense contractors.

[120] *History of the Ammunition Industrial Base*.

[121] Anderson, Piggee and Bingham, "The Current State of the Army."

[122] Perna and Abney, "A Case for Change in the Management of Class V."

[123] Vedat Bayram, "Optimizing the capacity and operation of U.S. Army ammunition production facilities," Master's thesis (Monterey, CA: Naval Postgraduate School, June 2002), pp. 4, 10, http://calhoun.nps.edu/bitstream/handle/10945/5966/02Jun_Bayram.pdf?sequence=1. This information was extracted from "Cost-of-Ownership Study Update for Munitions and Armaments Center," PricewaterhouseCoopers, 2001.

[124] Association of the United States Army, "The Army's Organic Industrial Base: Providing Readiness Today, Preparing for Challenges Tomorrow," *Torchbearer Issue Paper*, December 2013, p. 2, https://www.ausa.org/sites/default/files/TBIP-2013-Armys-Organic-Industrial-Base-Providing-Readiness-Today-Preparing-for-Challenges-Tomorrow.pdf.

[125] *Arsenal Support Program Initiative*, Public Law 106-398, Statute 1654, Section 343 (30 October 2000), http://www.gpo.gov/fdsys/pkg/PLAW-106publ398/html/PLAW-106publ398.htm.

[126] Congressional Budget Office, *An Analysis of the Army's Arsenal Support Program Initiative* (Washington, DC: U.S. Government Printing Office, July 2010), p. 4, https://www.cbo.gov/sites/default/files/07-21-aspi.pdf.

[127] AUSA, "The Army's Organic Industrial Base," p. 3, https://www.ausa.org/sites/default/files/TBIP-2013-Armys-Organic-Industrial-Base-Providing-Readiness-Today-Preparing-for-Challenges-Tomorrow.pdf. See also U.S. Army Materiel Command, *The Metal Book: Partnership Opportunities with the Army's Depots, Arsenals and Ammunition Plants* (Washington, DC: U.S. Government Printing Office, 2015), http://www.amc.army.mil/amc/partnering/MetalBook.pdf.

[128] GAO, *Defense Logistics: Army Should Track Financial Benefits Realized from its Logistics Modernization Program*, GAO-14-51, 13 November 2013), pp. 3–4, http://www.gao.gov/assets/660/658969.pdf.

[129]*Ibid*., p. 7. Also, a spinoff from Lockheed Martin in 2012, Savi Technology, provided the Army with SmartChain, a computer program that tracks and manages high-value assets in enterprise resource planning applications such as the Logistics Modernization Program.

[130]C.K. Prahalad and Gary Hamel, "The Core Competence of the Corporation" *Harvard Business Review*, vol. 68, no. 3, May/June 1990, https://hbr.org/1990/05/the-core-competence-of-the-corporation.

[131]Department of the Army, *Army Organic Industrial Base Strategic Plan (AOIBSP) 2012–2022* (Washington, DC: U.S. Government Printing Office, 2012), p. 2. See also Association of the United States Army, "The Army's Organic Industrial Base," pp. 2–3.

[132]John G. Ferrari, "Transferring Conventional Munitions Industrial Base Capabilities to the Public Sector," *Defense Acquisition Review*, July 2009, pp. 159–169, http://www.dau.mil/pubscats/pubscats/arj51/ferrari.pdf.

[133]*Ibid*.

[134]Donald D. Whitfield, *The Ammunition Production Base—Past, Present and Future* (Washington, DC: The Industrial College of the Armed Forces, April 1993), pp. 1–2, http://www.dtic.mil/get-tr-doc/pdf?AD=ADA276895.

[135]Limitations on the performance of depot-level maintenance of materiel, *Code of Federal Regulations*, title 10, 2011: 2466, http://www.gpo.gov/fdsys/granule/USCODE-2011-title10/USCODE-2011-title10-subtitleA-partIV-chap146-sec2466/content-detail.html. Other Army Working Capital Fund sites have a statute that mandates a 50 percent ceiling, measured in dollars, on the amount of depot maintenance workload, ensuring sufficient workload to maintain this organic capability.

[136]AWCF Budget Estimates, http://asafm.army.mil/Document.aspx?OfficeCode=1200.

[137]Whitfield, *The Ammunition Production Base—Past, Present and Future*, p. 8.

[138]*Ibid*., pp. 4, 32.

[139]*Ibid*., p. 32; GAO, *Recent Trends in Federal Civilian Employment and Compensation*, GAO-14-215, 19 January 2014, p. 6, http://www.gao.gov/assets/310/305720.pdf. From 2004 to 2012, the federal non-postal civilian workforce grew from 1.88 million to 2.13 million (14 percent).

[140]GAO, *DoD Civilian Personnel: Improved Strategic Planning Needed to Help Ensure Viability of DoD's Civilian Industrial Workforce*, p. 34.

[141]Department of the Army, *AOIBSP 2012–2022*, p. 1.

[142]*Ibid*., p. 3.

[143]"New U.S. War Songs: One establishes a legend, another mocks the Nazis," *Life Magazine*, vol. 13, no. 18, 2 November 1942, p. 43. Frank Loesser wrote the song, "Praise the Lord," in 1942 through Famous Music Corp. There exists an ongoing controversy about whether Chaplain Captain William A. Maguire or one of his subordinate chaplains, Lieutenant Howell M. Forgy, actually uttered the famous "Praise the Lord" quotation.