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*Land Combat Systems*

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## LAND COMBAT SYSTEMS 2017

**ABSTRACT:** The Land Combat Systems (LCS) industry, as part of the overall defense industry, is critical to the U.S. and partner nation's defense security. For the purposes of this study, the industry is sub-categorized into two markets: Tactical Wheeled Vehicles (TWV), including Protected Vehicles (PV), and Combat Vehicles (CV). Tactical Wheeled Vehicles include light, medium, and heavy wheeled vehicles carrying personnel and equipment with a limited ability to carry weapons. Combat Vehicles include tracked and wheeled vehicles mainly used in a ground combat role. The purpose of studying the LCS industry is to analyze representative issues and dilemmas faced by firms, the Department of Defense (DoD), and the U.S. Government (USG). The LCS industry consists of a number of key domestic and international firms as well as government depot facilities. Within the TWV market firms often manufacture both commercial and military products, sometimes on the same assembly line. However, most firms in the CV market are solely military suppliers. Cyclic government demand is a key driver in the TWV and CV markets. In addition, government customers control many variables which directly impacts the success or failure of LCS programs and the respective success or failure of individual firms. Given the facts above and based upon the study team observations and analysis, the USG and DoD should consider expanding Foreign Military Sales (FMS) opportunities, updating logistical sustainment plans and practices, revising requirements generation and oversight of Science and Technology (S&T) and innovation, and consolidating efforts within the Defense Industrial Base (DIB). These changes will maximize efficiency, increase competition, incentivize innovation, and minimize cost while maintaining the optimum readiness level for the designated mission requirements.

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## **Industry Study Outreach and Field Studies**

### **On-Campus Presenters**

AT Kearney/Program Executive Office (PEO) Ground Combat Systems (GCS), Sterling Heights, MI  
Caterpillar, Peoria, IL  
Defense Logistics Agency, Land and Maritime, Columbus, OH  
Deputy Assistant Secretary, Plans, Programs, and Resources, United States Army, Washington, D.C.  
Navistar, Lisle, IL  
SAIC, Stafford, VA  
U.S. Marine Corps JLTV Program Office, Quantico, VA  
U.S. Marine Corps PEO, Land Systems, Quantico, VA  
U.S. Marine Corps Sustainment Panel

### **Field Studies - Domestic**

Aberdeen Test Center, Aberdeen, MD  
Allison Transmission, Indianapolis, IN  
AM General, South Bend, IN  
Anniston Army Depot, Anniston, AL  
BAE Combat Vehicles, York, PA  
General Dynamics Land Systems Headquarters, Sterling Heights, MI  
General Dynamics Land Systems Anniston Operations, Anniston, AL  
Joint Systems Manufacturing Center, Lima, OH  
Navistar Defense, Madison Heights, MI  
Oshkosh Defense, Oshkosh, WI  
PEO Ground Combat Systems, Sterling Heights, MI

### **Field Studies – International**

Iveco Defense Vehicles, Bolzano, Italy  
Krauss-Maffei Wegmann (KMW), Munich, Germany  
Leonardo Defense Systems, La Spezia, Italy  
Renk Transmission, Augsburg, Germany  
Rheinmetall MAN Military Vehicles (RMMV), Munich, Germany  
MAN Truck and Bus, Munich, Germany

## LAND COMBAT SYSTEMS 2017

### INTRODUCTION AND INDUSTRY DEFINED

In the spirit of Bernard Baruch's goal to "keep in touch with industry," the purpose of this study is to understand the behavior of the markets and industry participants, as well as the salient issues and dilemmas, associated with a representative industry critical to national security. As such, the Class of 2017 Land Combat Systems (LCS) Industry Study team investigated the development, production, fielding, and sustainment of military vehicles to identify and analyze strengths, challenges, and opportunities inherent in this important industry today. The study team had the privilege of meeting with U.S. Original Equipment Manufacturers (OEM) and defense firms as well as select European-allied partner firms. In addition, the team conducted literature reviews and analyzed firms' financial, marketing, and corporate structures. Through these meetings, briefings, plant tours, and associated research, common themes and trends emerged and provided a clearer picture of the health of the military vehicle industry.

To better understand and capture the salient points of those themes and trends, the study team used a variety of tools and frameworks such as Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis; Porter's Five Forces analysis; and Structure, Conduct, and Performance (SCP) analysis. In addition, the team was disciplined in the collection of Key Take-Aways (KTA) from each interaction including analysis of past and current conditions, challenges, and opportunities as well as, where appropriate, recommendations related to U.S. Government (USG) goals and its role in the industry. The resultant themes and trends were then compared with historical assessment products from previous military vehicle industry studies to identify the most important observations, evaluate firm strategy and government policy implications, and offer key overarching recommendations to improve industry performance with respect to national security requirements.

The team conducted a detailed study of firms and government organizations participating in underlying vehicle markets and engaging in political activities to produce military vehicles to the U.S. and international militaries. For the purposes of this study, the underlying market for military vehicles is sub-divided into a Tactical Wheeled Vehicle (TWV) market (which includes protected vehicles (PV)) and a Combat Vehicle (CV) market, illustrated in Appendices B, C, and D. TWVs include light, medium, and heavy wheeled vehicles carrying personnel and equipment with a limited weapons capability, with or without protective armor. CVs include tracked and wheeled vehicles mainly used in a ground combat role and usually equipped with extensive firepower. The military vehicle industry consists of a number of key domestic and international firms, some of which develop and produce commercial vehicles or primary components as their major effort.

Depending upon the system and its position within the life-cycle, the military vehicle industry varies from a monopoly, such as General Dynamics Land Systems (GDLS) manufacturing M1 tanks and BAE Systems Inc. manufacturing Bradley Fighting Vehicles (BFV), to a competitive oligopoly in the TWV market, with several firms capable of producing vehicles from a Technical Data Package (TDP). Once a contract is awarded, a firm may enjoy a monopoly market as it remains the sole supplier for the duration of the program's life-cycle. Additionally, firms strive to secure contracts for follow-on procurements or acquire another firm with an existing contract through merger or buyout. Otherwise, most firms operate within a competitive oligopoly, where several key defense firms continue to challenge one another for

profitable contracts and logistical support during the life-cycle of a vehicle. Overall, the complexity of manufacturing and sustaining CVs, complicated by a limited number of firms with the inherent knowledge to do so, forces the USG and Department of Defense (DoD) to increase oversight and involvement in the CV market to maintain capacity and meet demand. On the other hand, the production of TWVs, which shares commonality with commercial vehicles, requires less direct USG and DoD involvement as several firms are able to meet demand when needed.

As noted above, the study team researched underlying military vehicle markets in order to better understand the health of the industry and its ability to satisfy national security requirements. The remainder of this paper is organized to showcase the results of that research with both domestic TWV and CV markets having dedicated sections describing current market conditions, challenges, and future outlook. An additional section provides observations of and comparisons with European markets based on a limited study of select industry participants on that continent. Based on the content of these three analytical sections, the study team identified cross-cutting themes worthy of additional comment to include international export/sales, emerging threats and investing in the future, requirements generation, and sustainment and supply chain management. Finally, the paper closes with several key recommendations for the USG and DoD to consider to assure market stability and longevity. Before starting the market analysis sections, a brief diversion into industry history and background is in order.

## **THE LAND COMBAT SYSTEM INDUSTRY HISTORY AND BACKGROUND**

Military ground vehicles provide needed capabilities for the U.S. Army, United States Marine Corps (USMC), and partner nations. Ground forces depend heavily upon the offensive capability of CVs and the expeditionary and mobile strengths of TWVs. Both types of systems provide a strategic advantage to enable Soldiers and Marines to operate in austere environments against formidable threats. However, the changing dynamics of the battlefield in recent conflicts with respect to improvised explosive devices (IED) forced a strategic shift in vehicle design, ultimately requiring heavier and more survivable systems. These design changes forced the military vehicle Defense Industrial Base (DIB) to respond accordingly and replace less survivable platforms with those that could counter more proliferated use of IEDs.

In general, industry firms in the DIB must account for the cyclical environment of shifting demand, declining budgets, and ever-changing requirements levied upon them by DoD and Congress. The firms in the TWV market fare better than firms in the CV market due to commonality of products across both the Defense and Commercial product lines. Similarly, component manufacturers supporting the TWV industry produce engines, transmissions, and other major components mainly for commercial vehicles with a separate product line specifically designed for defense markets. However, given the draw-down of military forces following major combat operations (MCO) in Afghanistan and Iraq as well as budget austerity, firms in both the TWV and CV industries wrestle with declining demand, USG desire to own TDPs, cancelled programs, protests, delayed budgets, and changing requirements.

Drawdowns in Iraq and Afghanistan, complicated by the Budget Control Act of 2011, capped military spending and limited future defense budget top lines.<sup>1</sup> In general, military vehicle firms experience increased competition for fewer, new procurements during periods of budget austerity.<sup>2</sup> In a few cases, such as the Assault Amphibious Vehicle (AAV) and Family of Medium Tactical Vehicles (FMTV), a rival competitor beat out the likely incumbent for follow-

on upgrades in the former program, and the subsequent rebuy of vehicles in the later. In these cases, the USG owned the TDP, which increased the likelihood it could successfully compete a rebuy of these existing vehicles rather than continue to do business with the incumbent firm.

Even so, military vehicle firms understand the magnitude of the opportunity inherent in a new program start, given the history of past government purchases. As an example, AM General initially won a five-year, 55,000 vehicle contract for the High Mobility Multi-purpose Wheeled Vehicle (HMMWV) that evolved into more than 230,000 vehicles sold to the DoD in almost three decades due to supplying a unique vehicle.<sup>3</sup> Given the high stakes associated with these contracts, firms sometimes protest new DoD contract awards, as was the case with the FMTV rebuy in 2009 and twice in the Joint Light Tactical Vehicle (JLTV) program.<sup>4,5</sup> There is no guarantee on the duration of a program however, once the USG awards a contract. The USG is generally permitted “to terminate a contract, in whole or in part, at the government’s convenience,” when budget or performance dictates.<sup>6</sup> Additionally, the extent of the program sometimes remains open-ended. In the case of the FMTV A2, the program is slated for 2,400 vehicles, but the “actual quantities in any future award are undetermined and will depend on proposed pricing for this quantity, army requirements, and availability of future funding.”<sup>7</sup> Therefore, firms never truly know the full extent to which a contract will be executed, especially given the budgetary crises of recent years. Finally, as firms decide to compete for a contract, they choose to invest significant capital and resources to provide a high-quality yet affordable product without any knowledge of the level or extent of competition. In one case, a firm spent extensive capital to win a contract, only to discover after the fact they were the only firm submitting a bid.<sup>8</sup> On one hand, the lack of knowing whether another firm would offer a proposal drove down cost for DoD due to the firm’s desire to provide a competitive offer. However, the firm’s return on investment was lower due to spending more on a proposal than needed to compete against ghost rivals.

While all of these conditions limit efficiencies and increase risk for firms, the market continues to deliver quality vehicles to DoD for sustained combat operations. In most cases, firms remain in the industry because of the potential for a lucrative contract when DoD starts a new program. Additionally, even if a firm’s business with the DoD accounts for only as little as one percent, DoD often remains the single largest customer for that firm. While these defense firms remain in the industry for those reasons, the USG and DoD must look to reduce inefficiencies where able to maintain a capable and responsive industrial base. As such, the next sections will showcase the study team’s market analyses as a means to better understand these potential inefficiencies.

## **DOMESTIC TACTICAL WHEELED VEHICLE (TWV) MARKET**

### **Current Conditions**

Ultimately, the TWV market is relatively stable given the commonality with commercial products. The TWV market is able to leverage design, Research and Development (R&D), facilities, and skilled personnel between defense and commercial markets. Most of the firms producing TWVs also produce heavy trucks (i.e. waste removal, cement mixers, firetrucks, buses) or have complimentary businesses within the firm. As a result, there is the equivalent of “warm basing” in the TWV market, where firms maintain the expertise and product line

capability to ramp up production of TWVs if needed with minimal USG or DoD involvement to maintain that capability.

Given the inherent expertise, the TWV market sector weathered the “bathtub” years of decreased demand in relatively good shape (See Appendix E, Figure 1). With increasing demand and potential relief to budget caps, firms are poised for what is projected to be near-term growth. TWVs remain the backbone of the U.S. military’s expeditionary mission and are therefore specifically designed for rough terrain, environmental extremes, and survivability. Still, they are largely built with the same parts and components (i.e., engines, tires, transmissions, and wheels) used in manufacturing U.S. and foreign commercial trucks.

Prior to 2004, militaries around the globe were generally satisfied with the survivability of the TWV, shown by the extensive use of the HMMWV. However, given the current threat and widespread use of IEDs, U.S. and European militaries required increased armor for their TWVs. Additionally, the added weight of protective armor was compounded by the requirement to carry a variety of command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) equipment. Other unique military requirements include scalable armor cabs and kits, advanced suspension and suppressive/remote weapon systems, and modifications for hauling military payloads and palletized systems in a variety of combat theaters.

The evolution of TWV into heavier armored vehicles stems from the military requirement to protect Soldiers and Marines from IEDs as well as the political requirement to safeguard America’s human capital. One could make the argument TWVs and PVs were once separate classes, depending upon whether DoD intended to operate the vehicle in a threat environment. As survivability requirements changed however, almost every TWV is protected, further blurring the lines between TWVs and PVs. For example, DoD originally intended for the HMMWV to serve as a light, highly mobile, and unarmored vehicle. However, to meet modern threats, DoD increased the HMMWV’s performance and protection requirements while also raising costs of the up-armored variant. Unfortunately, the up-armored HMMWV (UAH) still did not satisfy evolving requirements, requiring the U.S. Army and USMC to acquire the JLTV, which meets the requirement for personnel protection. The added requirements place the average procurement unit cost (APUC) for the JLTV at \$300,000, compared with the APUC of an up-armored HMMWV of approximately \$200,000. Still, the cost of JLTV with full protection is favorable compared to the APUC of \$430,000 to \$900,000 for the MRAP Family of Vehicles (FoV) acquired through rapid acquisition programs at the height of the wars.<sup>9</sup>

## **Challenges**

Shown by the abundance of firms responding to DoD demand for new armored vehicles, the TWV market has a moderate to high threat of new entry. Compared to other military platforms, potential new entrants have the ability to leverage expertise in truck production and the availability of many TWV complimentary components such as tires, shocks, engines, transmissions, and commercial chassis design foundation. The study team utilized Harvard Business School professor Michael Porter’s Five Forces tool to analyze the internal market factors influencing suppliers, existing firms in competition, and buyers to determine where power lies in the market. Additionally, external factors affect firms and buyers in the market including the possibility of new entrants or substitutes to existing products.<sup>10</sup> When competing for a contract to deliver TWVs to a military customer, U.S. firms who lack the infrastructure, access to economies of scale, technology and

sophisticated design knowledge, or who simply wish to gain access to an existing vehicle design, can partner with foreign firms with such access in a synergistic strategy to grab competitive market share. However, other critical entry barriers exist and include DoD relationships with incumbents and onerous USG Federal Acquisition Regulations (FAR) and Defense Contracting and Auditing Agency (DCAA) accounting rules.<sup>11,12</sup>

In addition to regulations and contract rules, DoD strives to maintain buyer power, especially in the TWV market, by becoming more aggressive in “seeking to acquire the design rights” of TWV programs “to facilitate competition for [secondary] manufacturing” of those vehicles from a different competitor.<sup>13</sup> Former Secretary of Defense (SECDEF) Dr. Ashton Carter directed Program Managers (PM) to consider purchasing TDPs to solicit “bids for build-to-print contracts. Without the TDPs, the government is often forced to sole source future lots, and often at higher prices.”<sup>14</sup> With ownership of the JLTV TDP following the initial eight-year, \$6.7 billion, 17,000 vehicle contract, DoD could conceivably reintroduce competition for the remainder of the JLTV life-cycle, which is expected to extend to 20 years, \$30 billion, and 55,000 vehicles.<sup>15</sup>

DoD’s ownership of TDPs however, remains a contentious issue for firms. Most OEMs view TDP transfer as a threat to their Intellectual Property (IP) and proprietary engineering practices. Therefore, firms must balance the cost of the competition and the value of any IP within the TDP with expected profits from winning the competition. Even if a firm wins a contract, the subsequent loss of competitive advantage when the TDP is delivered to a competitor in a follow-on contract may not be worth the initial profits. Additionally, some TDPs are not maintained to reflect the latest configuration, and the drawings are dated such that DoD cannot deliver accurate drawings to another contractor to re-compete the purchase of additional systems. Finally, a firm may make technical modifications to a vehicle, which DoD prefers, prior to a rebuy. If DoD did not contract with the firm to keep the TDP updated, switching to another contractor for existing weapons systems without updated TDPs may not be possible.

Given DoD’s uncertain demand, TWV firms have been forced to consolidate over the past twenty years, leading to dominance by only a few firms. Still, rivalry within the TWV market can be intense, especially in the early phase of competition for TWV contracts.<sup>16,17</sup> A major reason is the “winner take all” aspect of DoD contracts, with the more profitable life-cycle sustainment contracts serving as a tempting lure. Internationally, the market is even more competitive due to USG regulations regarding foreign competition for sensitive defense contracts. Conversely, U.S. firms face headwinds, more so when competing in the international market due to U.S. export controls and less so, by their frequent communicate that foreign governments often subsidized their competitor’s pricing. Additionally, foreign customers sometimes desire U.S. firms to provide offset agreements, which may include manufacturing certain aspects of the TWV or its components in the foreign country.<sup>18,19</sup>

In addition to the interest in maintaining the vehicle industrial base, DoD also has a critical interest in the component market for TWVs as they are essential to the success of the overall TWV market. Engines and transmissions, which may share commercial designs depending upon the vehicle, are the most visible component markets for TWV. While these components for TWV share extensive commonality with commercial products, they require some modification for military use. As such, firms supplying components to vehicle OEMs face similar market conditions.

In the component market, an example of a major supplier to DoD is Caterpillar, which produces engines for mid-range and heavy duty tactical vehicles for the U.S. Army, Navy, and

USMC, such as the FMTV, the Heavy Expanded Mobility Tactical Truck (HEMMT) family of vehicles, Palletized Loading System (PLS), and the Stryker family of vehicles.<sup>20</sup> Additionally, Caterpillar provides engine, transmission, and transfer case power packs to support the U.S. Army's Caiman, and the Navy and USMC's MRAP and Buffalo vehicles.<sup>21</sup> Within the U.S. TWV market, Caterpillar currently has over 85 percent of the market share in mid-range and heavy duty tactical vehicle engines.<sup>22</sup> Furthermore, there are over 125,000 Caterpillar engines and over 12,000 Caterpillar machines in service with the U.S. military.<sup>23</sup> While Caterpillar's sales for defense and federal products constitutes 1.1 percent of the company's sales, DoD remains Caterpillar's biggest customer.<sup>24</sup>

For its commercial products, Caterpillar operates an extensive dealer network providing worldwide support and direct sales to units providing customer support for the life of the product, which includes warranties on refurbished engines.<sup>25</sup> While this business model provides long-term value to the commercial customer, the disconnect between Caterpillar's business model and DoD's purchase criteria is the firms' focus on life-cycle value versus up front discounts. DoD usually prefers lowest cost, technically acceptable (LPTA) contracts, which places emphasis on up-front cost versus life-cycle cost and value over time. If DoD procurement budgets remain the same or decrease, this focus on near term costs over life-cycle sustainment costs could negatively impact Caterpillar when competing its engines for future DoD contracts. Additionally, DoD may see an increase in long-term Operations and Maintenance (O&M) costs due to operating less reliable equipment.

Overall, firms left in the TWV industry weathered the recent bathtub years through a mix of internal manufacturing process efficiencies and optimization, corporate consolidations, and in a few cases, innovative and effective strategic planning to stay one-step ahead of the competition. In other cases, some firms managed to just maintain their minimum sustaining rate through lean years.<sup>26</sup> The TWV industry has been able to do this in large part given its foundation in the commercial truck manufacturing sector. However, while the overall industry remains relatively healthy, there is room for improvement to ensure the TWV industry remains capable and robust enough to provide effective and sustainable platforms for DoD and allied customers. Ensuring effective competition in the global market is critical to the TWV industry's long-term success and to U.S. national security.

## **Outlook**

Given the number of firms with knowledge and expertise to produce TWVs, DoD can expect the market to remain healthy. Firms in the TWV market responded well to DoD demand for a different type of vehicle, providing capable MRAPS on short notice. These firms learned manufacturing techniques and gained industrial knowledge to produce armored TWVs, allowing many of them to enter competition for JLTV, thus providing DoD with several robust choices for down-select to the final vehicle. As DoD looks ahead to future contracts to meet national security requirements in the mid and long-term outlooks, it can expect multiple firms in the automotive industry to compete intensely, thus offering DoD a high-quality product at a reasonable price. The way forward will entail collaboration between the TWV industry, USG, and DoD through effective communication, transparency, and technological innovations fundamental to the endeavor. With some revisions in FMS policies to enable U.S. firms to compete better in the international market, DoD can continue to provide the most effective TWV platforms to the warfighter.

## DOMESTIC COMBAT VEHICLE (CV) MARKET

### Current Conditions

In direct contrast to the TWV market, the CV market requires specialized expertise and production capability to manufacture military-unique vehicles with limited to no commercial commonality. Barriers to entry into this market are high, such that a new firm not currently producing CVs will most likely be unwilling to accept the risk, or spend the capital required to develop the infrastructure to enter and produce CVs. It is important to note here, “high” barriers to entry do not imply “no entry.” Rather, it implies that entry will be limited to a very small number of firms that can find a way to overcome the barriers—e.g. through partnerships, acquisitions, or mergers. While TWVs are the desired solution for wars in Afghanistan and Iraq, the increasing threat from Russia results in a growing appetite for CVs, especially from North Atlantic Treaty Organization (NATO) allies. Unfortunately, inefficiencies in the CV market, mainly due to multiple facilities with redundant capabilities and low throughput, threaten DoD’s capability to sustain critical combat power due to the high cost of maintaining these facilities for limited demand.

DoD must maintain a robust CV industrial base as CVs are the backbone of U.S. military might. A Main Battle Tank (MBT) is one of the most intimidating ground weapons systems with an ability to deter less capable enemies from taking any action against U.S. or allied forces.<sup>27</sup> Without the capability provided by the CV marketplace in response to DoD requirements, the United States would not be able to project land power against near peer competitors in support of its strategic vision. DoD must be prepared to face a rising China or a resurgent Russia, as well as lesser threats from North Korea and Iran. These potential threats will undoubtedly require the overmatch capability of CVs to persevere in a MCO, something the U.S. Army believes is stagnating with the M1 Abrams.<sup>28</sup>

Unfortunately, the current CV industrial base suffers from a diminished number of capable firms in the United States. When the U.S. Army first acquired the M1, there were seven firms or major technology suppliers within the CV industry. However, through mergers and buyouts, the CV industry decreased to only two U.S. primes (See Appendix E, Figures 2 through 4).<sup>29</sup> What was once a decidedly competitive market served by multiple firms, is now significantly less competitive and reduced down to only two main competitors—GDLS and BAE. GDLS is the OEM of the M1 main battle tank, the 8x8 Stryker Armored Combat Vehicle, and the Light Armored Vehicle. BAE is the manufacturer of the M2 Bradley Infantry Fighting Vehicle (IFV), the M113 Armored Personnel Carrier, the M109A6 Paladin self-propelled (SP) howitzer, and is competing for the USMC Amphibious Combat Vehicle (ACV) in partnership with Iveco. Effectively, DoD is beholden to GDLS and BAE for sustainment of current CVs in operation.

Given the state of the CV DIB, some interesting market changes have occurred that set the CV market apart from the TWV market. As an example, when the USMC competed the AAV Survivability Upgrade Program (SUP) in 2014, SAIC unseated the incumbent BAE, the firm responsible for the AAV following acquisition of United Defense. SAIC succeeded not as an experienced CV manufacturer but as a systems engineering integrator. The former requires huge outlays of cash and institutional knowledge on production of CVs while the latter allows SAIC to integrate choice components into a competitive product. While it is still too early to tell whether SAIC’s business model will prevail, they do introduce a new strategy that inserts a level

of intensity in the competition for new programs. While there has not been a large-scale new CV program since the USMC canceled the Expeditionary Fighting Vehicle (EFV) in 2011, DoD's decision to switch from BAE to SAIC for the AAV survivability upgrade may entice other firms to enter the competition for new programs including the Mobile Protected Firepower (MPF), Next Generation Combat Vehicle (NGCV), and future service life extension programs (SLEP).<sup>30</sup>

## Challenges

While the tracked CV design requires certain manufacturing expertise, wheeled CVs and SLEPs are more open for new entrants. Wheeled CVs have a relatively simple design with respect to power and maneuver, however tracked CV technology requires institutional knowledge, specific manufacturing abilities and facilities, and a large outlay of cash to begin production. This is unlike the widespread institutional knowledge and capital investment in the TWV market. Very few firms have the infrastructure and technical capability to design, develop, and manufacture a tracked CV. If DoD required a new MBT to replace the M1, it is almost a certainty firms submitting a proposal would be limited to those already active in the CV market.

As such, DoD does not have much negotiating power in the tracked CV market. Looking specifically at GDLS and the M1 Abrams, a tremendous amount of power transferred to GDLS over the past 40 years as GDLS is the only firm currently capable of manufacturing M1 tanks domestically.<sup>31</sup> Being a sole source provider for the entire life-cycle of the M1 affords a measure of control. Given the history of M1 manufacturing and refurbishment, DoD is reliant upon GDLS and pays to maintain the CV infrastructure at both Joint Systems Manufacturing Center (JSMC), a Government Owned/Contractor Operated (GOCO) facility in Lima, Ohio, and Anniston Army Depot (ANAD) in Alabama.<sup>32</sup>

Despite the U.S. Army publicly stating in 2012 it did not require future M1 builds, the political fallout of closing JSMC led Congress to intercede and allocate \$183 million, which allowed JSMC to remain in operations. This funding continued in the next two years with Congress spending another \$120 million in 2014.<sup>33</sup> Congress allocated funding to keep the production lines open without competition due to sole source contracting. While JSMC remains open for M1 production capability, current and future operations rely on its partnership with ANAD. The partnership is required because the M1 and Stryker workload is split between the two commands and physical locations. With DoD's decision to reset or remanufacture M1 tanks through life-cycle extensions rather than purchasing new ones, JSMC and ANAD remain critical facilities. However, DoD pays a high premium to maintain the domestic CV industrial capability while a significant portion of JSMC's production supports international sales. In fiscal year 2017, 54.9 percent of the scheduled workload supported export sales.<sup>34</sup> Ongoing export work includes CV sales for Israel, Morocco, Saudi Arabia, and Egypt.<sup>35</sup>

Similar to the CV market, DoD pays a high premium to sustain the component market for CVs. While many firms have the industrial knowledge to supply components for TWV, very few firms have the knowledge or desire to supply very specific components for CVs. As such, USG and DoD roles in the CV component market mirror the roles in the CV market. There are only three transmission manufacturers for the domestic CV market who are sole source providers on three CV platforms. Allison provides the X1100 cross-drive transmission used in the M1 Abrams and the XT200 used in the M113, and Twin Disk now produces the XT-1410-5A for the M88.<sup>36</sup> L3 provides the HMPT-500 transmission for the M2 Bradley family of CVs.<sup>37</sup> With these vehicles in sustainment and no new CV procurement programs on the horizon, the demand

for new transmissions is low. Despite the inefficiency of maintaining the supplier base for new transmissions, DoD pays a high cost to maintain the capital infrastructure for transmissions due to not having another source capable or willing to produce a niche component. Much like appropriations maintaining the JSMC facility, DoD also allocates money for government owned tooling within Allison's plant-14 to make the M-1 X1100 tank transmission. While Allison has a robust self-financed commercial transmission plant producing both commercial and military grade TWV transmissions, it relies upon DoD funding to sustain minimal operations to support the X1100 tank transmission. Overall, the challenge to the USG and DoD is the high cost of maintaining a warm manufacturing line for both CVs and components with the goal of having the ability to surge production capability in a relatively shorter time than if a facility were closed and had to be re-opened when needed.

## **Outlook**

If DoD maintains the status quo, it risks losing manufacturing and sustainment capabilities for CVs as other nations. With only two major primes focused on developing and manufacturing CVs, and an assortment of other defense firms such as Lockheed Martin, SAIC and Textron that, on occasion, compete for selected CV programs as a prime or major partner, DoD must decide how to maintain the DIB capability of manufacturing tracked and wheeled CVs. Additionally, DoD must decide how to maintain a domestic supply of key military unique CV components such as gun barrels, forward looking infrared (FLIR) cameras, engines, track, and tracked vehicle transmissions. Low demand for CVs forces the DoD to pay a high premium for operations to reset, remanufacture, and sustain the fleet of CVs. Therefore, the future health of the CV industrial base remains questionable with respect to U.S. inherent capabilities to manufacture new tanks or other tracked vehicles to meet national security requirements. Unlike the response to new TWV programs, if DoD requires new technology in a main battle tank or infantry fighting vehicle, it may be forced to rely upon the same two CV primes pending any new firm trying to enter the market with a different business model, as SAIC did for the AAV Survivability Upgrade.

If DoD wants to re-invigorate the CV industry and realign precious resources from maintaining a warm M1 industrial capability, it must alter its budget strategy. Possibilities include consolidating CV capabilities or inserting competition into existing facilities. With only one contractor overseeing operations at JSMC, DoD is enabling inefficiencies in the industrial base by paying for overhead used by only one firm. Inserting competition by allowing other firms to use JSMC may lower the cost of maintaining the DIB. Additionally, demand for CVs is increasing, especially in Europe to counter the increasing Russian threat and aggression. The next few years are an opportunity for the USG to look carefully at relaxing the barriers to international sales to stabilize the CV market. Additionally, further relaxing barriers that impede close collaborative partnerships with some of the highly capable international CV firms for future CV programs and components, especially with those of our closest allies, may expand our own industrial capability, increase technological competency, and lower costs.

## EUROPEAN MARKETS: KEY OBSERVATIONS AND COMPARISON WITH DOMESTIC MARKETS

To better understand DoD practices with respect to managing the DIB according to U.S. culture, laws, policies, and practices, the study team investigated specific European defense firms in Germany and Italy. The research surfaced some interesting similarities as well as key differences. One observation was European markets include a broader DIB due to each sovereign state desiring to protect its domestic capability to produce weapons systems (See Appendix E, Figures 5 and 6). Additionally, defense contractors' practice of lobbying Congress and DoD for contracts is somewhat unique to the United States. Foreign firms are less successful at lobbying government representatives or generating influence by paying into campaign funds. This could be an indicator of a weaker "power of the purse" in some countries. This difference, along with lack of government support for R&D and more restrictive policies for foreign sales in some cases, introduce unique market conditions. By way of background, major European manufacturers currently active in the TWV market include Iveco Defense Vehicles, Mercedes, Rheinmetall MAN Military Vehicles, and Renault Truck Defense. The biggest names in the European CV market include General Dynamics European Land Systems (GDELS), Krauss-Maffei Wegman (KMW), Rheinmetall, Nexter Systems and Iveco. In the component market, the German firms Renk and ZF Friedrichshafen AG top the transmission-manufacturing list, while MTU is the leading supplier of combat vehicle engines.

As in the United States, the European market in recent years witnessed a trend of declining national defense budgets, which in turn led to a decrease in the production of military vehicle platforms. At the same time, increased survivability design requirements for both legacy and future TWVs and CVs, especially for militaries aligned with U.S. operations in Iraq and Afghanistan, pushed the limits of European vehicle performance. Consequently, firms increased funding in the R&D and Science and Technology (S&T) arenas to attempt to meet changing requirements. Finally, several European firms noted protection of their TDP and IP as an increasing challenge for them in securing government contracts, much like in the U.S. sectors.

With respect to European and U.S. cooperation, both U.S. and European firms have a strong desire to enter each other's markets, but with limited success due to incumbency, intellectual property protections, and sovereign protection of their respective DIB. However, successful firms do partner with U.S. firms, matching high quality European products with established U.S. access to the TWV, CV, or component programs. As an example, Iveco Defense's partnership with BAE in the CV markets provides a model of a foreign firm partnering with a U.S. firm to enter the domestic U.S. market. As an illustrative component example, Renk—on the international market—is the largest competitor to U.S. transmission firms for CVs and ships. While Renk already established itself in over 30 armies and 40 navies worldwide, to include the U.S. Littoral Combat Ship, it has yet to successfully compete and enter the U.S. market for CVs despite a desire to supply transmissions to DoD.<sup>38</sup> A partnership opportunity may exist with Renk for example, to expand our own technical component competencies and increase industrial capability for CV transmissions, thereby capitalizing on economy of scales to lower overall costs of production.

As firms on either side of the Atlantic eye opposing markets, the European market remains more monopolistically competitive than the U.S. markets given the broader prevalence of more military vehicle firms and a diverse pool of ground platforms. This diversity is due in large part to the differing needs of each European member state's military and national security requirements,

particularly in the CV market. Additionally, European states have a high desire to protect their domestic capacity to produce weapon systems rather than rely upon other European states for national defense. As such, multiple programs and platforms yield more competition and innovation, resulting in less need for state support, allowing the market to determine winners and losers more so than in the United States.

The competitive market and overall reduced demand for LCS products however, resulted in a renewed trend of mergers or partnerships among European firms. The December 2015 merger of German private company KMW with French government owned Nexter Systems, forming the joint umbrella firm KMW Nexter Defense Systems (KNDS), is one such example. The desire to align European interests in the defense industry in a more efficient and productive manner drove the KNDS merger. This merger was similar to the way Airbus aligned European aircraft design and production efforts, thus becoming the number one competitor to Boeing in the United States. Typically, mergers like KNDS should result in a more competitive and sustainable set of military vehicle firms, leading to cost-efficient operations, reduction in duplicative capabilities, and greater access to international customers with defense capability requirements. Additionally, integrating the European defense industrial base should promote greater commonality and interoperability amongst the various ground systems within the European member states.

Conversely, cross-pollination of technologies within the combined portfolio could provide opportunities to tailor specific offerings to customers' needs without significant new R&D investment, enhancing the combined portfolio's competitiveness. In reality, the KNDS endeavor faces several challenges, including overcoming disparate German and French national interests and efforts to maintain control of national security sensitive technology exports. These and other sovereignty related issues could inhibit effective corporate decision making, slow down or prevent the new corporation from realizing significant benefits anytime soon, and most importantly, demonstrate to other European firms the pitfalls of entertaining such consolidation.

These pitfalls are reflective of a broader challenge facing European military vehicle markets. While organizations such as the European Union (EU), NATO, and the European Defense Agency (EDA) guide member states, there is little consensus in Europe with respect to foreign policy, requirements, logistical support practices, and demand for land combat systems. The membership rosters of these and other European Security Initiatives alone make for complex agreements on a common set of issues (See Appendix E, Figure 7). For example, the 2003 U.S.-led war in Iraq divided EU members on whether or not to provide support. Given the makeup of twenty-eight nation states with different cultures, histories, and relationships, it is inevitable there will be differences in viewpoints with respect to foreign and defense policies (See Appendix E, Figure 8).<sup>39</sup>

Some see the threat from Russia as having the potential to coalesce European defense requirements such that firms partner together to produce military vehicles in order to meet multiple states' requirements. Given the threat, there is the possibility European states will spend more on defense than previous years to counter Russia's expenditures, which have steadily increased over the past few years (See Appendix E, Figures 9 through 11). However, European security agreements remain a difficult venture as each European state sees the threat from a different perspective. While some states look east to Russia, others look south to Africa, and still others remain entrenched in a Cold War mindset.<sup>40</sup>

As European firms assess their strategy with respect to aligning requirements with other firms across the continent, they also look globally for opportunities to export their products. However, most European firms face a similar challenge to exports as in the United States with

government policies sometimes placing home based firms at a competitive disadvantage globally. For example, German firms must comply with German government standards related to export control under the strict War Weapons Control Act, the German Federal Office of Economics and Export Control (BAFA), as well as those of the European Foreign Trade Act regulations.<sup>41</sup> The BAFA law regulates critical defense product exports with the main intention to not cause problems in foreign relations that contribute to the initiation of new conflicts or violation of human rights in contested states. This foreign policy is a direct result of German lessons learned based on the violation of human rights in WWII.<sup>42</sup>

As such, firm strategies have evolved to adapt to these regulations. For example, with a large global footprint of subsidiaries based in multiple foreign countries having different or less restrictive arms export regulations, Rheinmetall can produce equipment outside of Germany for sale to different buyers overseas. Currently, 77 percent of Rheinmetall sales are achieved abroad, while 23 percent are in the German defense market.<sup>43</sup> Elsewhere in Germany, firms like KMW and Renk overcame the lackluster investment by the German government, compared to USG investment to sustain the DIB, by innovating and increasing their own R&D budgets. As a result, KMW designed and produced an unmanned artillery system prototype with \$50 million of its own money.<sup>44</sup> This business model contrasts sharply with the U.S. model previously stated, where DoD funds low demand niche manufacturing areas such as JSMC and Allison's Plant-14 for the M-1 X1100 tank transmission. As such, U.S. firms seem to be more tolerant of cancelled programs and money spent on R&D and procurement due to more direct government support, whereas European firms are forced to seek alternatives and innovations given the risk assumed by the firm as opposed to the national government.

Despite the headwinds facing European firms, the quality of European military vehicles and components with partnerships such as KNDS, if successful, could potentially threaten U.S. firms' position in global exports. Compounded by years of low demand for military vehicles in both the United States and internationally, it behooves the USG to consider policies that would expand international sales opportunities for U.S. firms to market their products abroad, particularly in the CV market, including components such as CV transmissions. Given the restrictive policies in nations such as Germany, there is a very small window of opportunity for the USG to open the aperture for exports to bolster U.S. firms by sponsoring their entrance into niche foreign markets. Providing the opportunity for U.S. firms to sell to more international partners will provide stability as demands ebb and flow by region. Additionally, the USG should continue to encourage, and perhaps, further incentivize more partnerships between U.S. and European firms, such as the Iveco and BAE model, to help stabilize domestic firms fighting cyclical demand.

Overall, the European market has many similarities with the U.S. market with respect to defense firms adjusting strategies to meet demand and remain competitive globally. A key difference between the U.S and European markets is the limited involvement of European governments in providing direct monetary support, thereby forcing European firms to innovate and partner to maintain market share. As these firms continue to compete, the role of U.S. firms in the global market could diminish without invigorating export opportunities and cross-Atlantic partnerships.

## INDUSTRY CROSS-CUTTING THEMES AND OBSERVATIONS

### U.S. Arms Sales to Foreign Governments

The role of export sales in the United States is to introduce higher demand for U.S. products by opening global markets to U.S. firms and increase interoperability of allied militaries with U.S. forces. Compared to other government export systems and policies, the USG international sales model is relatively effective in supplying competitive products to foreign militaries around the globe. For example, a significant portion of JSMC production supports exports with almost 55 percent of the workload scheduled for international sales in Fiscal Year (FY) 2017.<sup>45</sup> For example, export sales for Israel, Morocco, Saudi Arabia, and Egypt represent CV platforms currently in production at JSMC.<sup>46</sup> Thus, international sales are critical to JSMC's and GDLS's business model because it generates a desirable workload to keep the production lines warm and supply chains active. However, with increasing foreign manufacturing and technological capabilities of military vehicles, and a rising threat from Russia and China, the USG must revise the model to invigorate the CV base and take advantage of a short window of opportunity to corner a portion of the defense market. While the export control system does allow U.S. firms to sell to allied nations, it can be cumbersome and inefficient, thus requiring some modifications to streamline the process.

The USG restricts export of defense items, "dual-use" goods, and technology as it balances national security, technology transfer, and export competitiveness in the global market. Defense items include anything "specifically designed, developed, or configured, adapted or modified for a military application."<sup>47</sup> Dual-use items are "commodities, software, or technologies that have both civilian and military applications."<sup>48</sup> Debate surrounds decisions to authorize or restrict export items to foreign partners and allies. Some view exports as enabling reverse engineering or IP theft, while others view restrictions as cumbersome, obsolete, or inefficient with respect to imposing unneeded obstacles to global market opportunities for U.S. firms. In 2009, President Obama launched a comprehensive review of the U.S. export control system followed by Congressional action changing some of the governing principles.<sup>49</sup>

The Export Administration Act (EAA) of 1979 is the underlying statutory authority for dual-use export controls and has been continued by the invocation of the International Emergency Economic Powers Act (IEEPA) before its expiration in 2001.<sup>50</sup> The Bureau of Industry and Security (BIS) in the Department of Commerce administers the dual-use export control system. The BIS establishes the Commerce Control List (CCL) composed of 10 categories of items further divided into functional groups.<sup>51</sup> For defense items, the Arms Export Control Act (AECA) of 1976 provides the President with the statutory authority to control the export of defense articles and services to friendly countries for the sole purpose of internal security and legitimate self-defense.<sup>52</sup> Finally, the International Traffic in Arms Regulations (ITAR) sets out licensing policies for exports of U.S. Munitions List (USML) items based upon the nature of the article and not the end-use or end-user of the item.<sup>53</sup>

Despite some changes by Congress, a majority of defense firms still consider the export process a bureaucratic nightmare. Due to all of these regulations and policies, the U.S. DIB faces what former SECDEF Robert Gates deemed a "byzantine amalgam of authorities, roles, and missions scattered around different parts of the federal government."<sup>54</sup> Some question the purpose of restricting items such as vehicle suspension systems simply because those suspensions are on a TWV. Others find it difficult to follow policy and fear missing an item on a

list different from the list they referenced. Finally, many see the restrictions as detrimental to sustaining the DIB during times of U.S. budget austerity when foreign partners generate a demand for U.S. systems.

The most glaring issue facing U.S. firms is that different government agencies share responsibility for export controls with limited synchronization. The Commerce Department is not connected to security cooperation priorities like the DoD, but DoD does not have the lead in FMS. Ironically, the State Department has the lead, but it is least connected to industry and what is needed to support the DIB.<sup>55</sup> Most firms stated the recent effort to reclassify some items from the USML and move them under Commerce Department control did not significantly streamline the export processes. Rather, they felt it only changed the agency with whom they must coordinate. Given the current state of the military vehicle market, especially with respect to CVs, and the still cumbersome export license process in place, the USG must investigate more efficient export control policies to spur global supply of U.S. weapons systems.

### **Emergent Threats / Investing in the Future**

Even if the USG relaxes export control policies to ease access to the global market, U.S. firms, especially those producing CVs, face significant challenges related to emerging threats and advancements in technology. Given the ‘peace dividend’ resulting from the collapse of the Soviet Union, the focus on counter-insurgency fighting over the past sixteen years, and Russia’s resurgence as a geo-political power, DoD must re-invest in CV S&T with respect to firepower, protection, and mobility, to regain U.S. primacy in the land domain. While DoD should actively pursue additional S&T funding, fiscal realities and Congress’ inability to pass a budget make the likelihood more S&T funding will become available extremely small. As such, DoD must maximize any and all S&T funding through better synchronization of the entire S&T enterprise, to include requirements, programming, and acquisition, while implementing a long-term strategy that is resource-informed using realistic fiscal assumptions. Only through optimized S&T practices will the U.S. DIB be able to compete with foreign manufacturers and face the rising threat.

In the past five years, Russia, Germany and the UK have all developed, tested, and initiated fielding of new tracked and wheeled CV platforms. Both Germany and the UK focused on new infantry fighting vehicles competing with U.S. firms. However, the real surprise entering the military vehicle stage is the Russian development of the new Armata family of heavy armor vehicles. The Armata has a common chassis used in Russia’s next generation MBT, IFV, recovery vehicle, and SP howitzer. While Russia is showcasing its new combat vehicle with potential technological advancements over the M1 Abrams, the U.S. Army is waiting until FY 2022 to even make a decision on whether to pursue development of the Next Generation Combat Vehicle (NGCV) or continue modernizing legacy M1 Abrams and M2 Bradleys. While DoD navigates the cumbersome and extensive procurement process, other systems threaten to beat U.S. defense firms to the global market or surpass U.S. capabilities on the battlefield.

Procurement of Army and USMC CVs begins with a requirement for a capability. Using the U.S. Army process as an example, requirements for CVs start at the Maneuver Center of Excellence (MCoE) at Fort Benning, with the Training and Doctrine Command (TRADOC) Capability Manager (TCM). The initial cut of the requirement then moves up through TRADOC with a significant amount of shaping from both the Army Capabilities Integration Center (ARCIC) and the Tank and Automotive Research, Development and Engineering Center

(TARDEC). ARCIC's role in requirements is to ensure the desired capability fits within ARCIC future concepts of warfare. The USMC has a similar process that is managed largely out of Quantico, VA.

TARDEC's mission is to develop, integrate and sustain the right technology solutions for all manned and unmanned DoD ground systems and combat support systems to improve current force effectiveness and provide superior capabilities for the future force.<sup>56</sup> In other words, TARDEC is doing early research in order to inform the MCoE what is in the realm of the possible when incorporating new technology into requirement development. Although TARDEC's core mission is S&T, it reports to Research Development and Engineering Command (RDECOM), which reports to Army Material Command (AMC). The TARDEC/RDECOM relationship with AMC is cumbersome because TARDEC/RDECOM are responsible for incorporating S&T into the early pre-requirement stages of the R&D of a combat vehicle, but then that combat vehicle does not come back under AMC's responsibility until it has finished procurement and fielding by the PEO.

Since the early 2000's, the U.S. Army G-8 has been responsible for the Planning, Programming, Budgeting, and Execution (PPBE) for all requirements and programs. The G-8 is the U.S. Army's lead for matching available resources to the defense strategy and the U.S. Army plan, which is accomplished through participation in defense reviews and assessments, the programming of resources, material integration, analytical and modeling capabilities, and the management of the Department of the Army studies and analysis.<sup>57</sup> Combat vehicle PPBE is managed within the Dominant Maneuver Division of G-8 Force Development (FD) Directorate. The G-8 provides Research and Development and Test and Evaluation (RDTE) and procurement funds to the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)) to develop and purchase CVs from industry.

A friction point reducing S&T effectiveness and value is the lack of synchronization between the applied research S&T community and those responsible for production development pertaining to priorities, funding and timing. Much of this disorganization can be attributed to how the U.S. Army is organized and what responsibilities lay within each organization. The G-8 is responsible for the vast majority of equipment modernization prioritization, funding, and timeline, which is supported by the Army Requirements Oversight Council (AROC) process and the Program Objective Memorandum (POM)/Strategic Portfolio Analysis and Review (SPAR). The AROC and POM/SPAR processes facilitate close interaction between the requirements, PPBE, and acquisition communities. However, RDECOM and its subordinate units, to include TARDEC, are only loosely synchronized with the G-8's AROC, POM, and SPAR processes. Instead, AMC provides the O&M funding, while ASA(ALT) provides the research, development and technology exploitation funding to perform their core mission. When ASA(ALT) provides the funding, they then dictate the long-term S&T priorities to TARDEC. Additionally, ASA(ALT) is part of the Army Secretariat and does not report to the Chief of Staff of the Army (CSA) who approves the POM and SPAR built and validated by the G-8. This organizational mis-alignment of requirements, funding, and oversight complicates procurement, leading to longer lead-times for the U.S. Army to acquire a new vehicle.

## **Requirements Generation**

In addition to cumbersome S&T and procurement practices, many programs stall or are cancelled during acquisition due to costs and shifting or unachievable requirements. As DoD

anticipates capabilities required to win the next war, parochialism, political influence, and acquisition policies often drive incongruent requirements for new military vehicles. For example, the desire to protect every vehicle from an IED adds weight and size and affects transportability and operational capability, which can increase procurement and life-cycle costs. In some cases, USG stakeholders (to include Congress) do not grasp the exact performance specifications needed to execute combat operations and the associated design trade-offs that must be made. Additionally, vague or changing requirements during a program's acquisition require firms to be versatile enough to meet new requirements. Increasing requirements along with design performance failures resulted in the USMC cancellation of the EFV after spending \$3 billion, as well as 22 U.S. Army programs canceled at a total cost of \$32 billion.<sup>58, 59</sup>

While some canceled programs referenced above also faced budget cuts unrelated to requirements challenges, most programs suffered from continuous changes in requirements due to shifting needs or a desire for vehicles to meet multiple operational requirements. Service requirements differ enough such that Congress and DoD cannot procure a "one size fits all" solution. For example, the USMC required the EFV to be launched 25 miles off shore, carry 17 combat-equipped Marines, swim at 20 knots in the water, and travel up to 345 miles at 45 kilometers per hour on hard surfaced roads.<sup>60</sup> While there were several technical issues with the EFV design, one of the shifting requirements included increasing protection of the EFV against IED explosions. The flat-bottomed EFV was overly vulnerable to IEDs due to a lack of a V-shaped hull, which can mitigate underbelly explosions. The long-standing concern of some in Congress for Soldiers and Marines to be protected against IEDs mandated a review of the program. The Marines countered, contending the EFV would have to be totally redesigned at a great cost to incorporate the V-shaped hull. They suggested adding underbelly armor applique after the EFV was ashore to provide necessary protection.<sup>61</sup> Either solution changed the original EFV specifically designed to maximize amphibious capabilities. As such, Congressional mandates for a re-design of the EFV led to an exponentially increasing cost, a Nunn-McCurdy breach, and eventual program cancellation.<sup>62</sup> Unfortunately, due to the expectation of procuring a new amphibious vehicle, the USMC spent less than \$10 million per year on sustaining the existing AAV fleet. After cancellation of the EFV, the majority of USMC amphibious capabilities rested upon an outdated vehicle originally designed in 1972.

While joint acquisition programs are assumed to be more cost effective, Services should seriously reconsider the increased cost per platform to meet specific requirements for satisfying each Service's needs. While not a joint program, the EFV story illustrates the impact of levying competing and incongruent requirements upon systems designed to meet specific service needs. In an attempt to avoid such problems, DoD should have transparent and frequent communication with contractors to determine feasible and cost-effective requirements, as well as tough negotiations between Services to determine which requirements are not critical to a Joint program.

## **Sustainment and Supply Chain Management**

Given the failed acquisition of several new programs designed to outfit warfighters with increased capability and newer systems to counter current and future threats, DoD is forced to sustain and maintain current ground platforms well beyond intended life-cycles. DoD determines whether ground vehicle programs require replacement, repair to a reasonable operating condition, recapitalization (refurbishment and upgrade to like-new capability), or

merely reset (“rejuvenation” to its original condition). These decisions depend upon available resources, current and emerging innovation, global competition and threats, and status of intended equipment life-cycles. While a decision for outright replacement triggers the acquisition cycle, repair, recapitalization, and reset are typically performed by a depot or OEM. Of note, U.S. law (Depot Maintenance Statute-10 USC 2466), also known as the “50-50 rule,” sets “a 50 percent ceiling, measured in dollars, on the amount of depot maintenance workload that may be performed by contract for a military department or defense agency during a fiscal year.”<sup>63</sup> Therefore, depots and OEMs remain critical to surge capability for the USG, as the next military vehicles off the line will come from one of the depots or refurbishment lines, rather than as a brand-new vehicle.<sup>64</sup>

Although DoD often pursues repair, recapitalization, or reset over outright replacement due to fiscal necessity, it often struggles to resource low-demand, low-production (and therefore low-profit) repair parts from industry, particularly for legacy CV and TWV programs. DoD leans heavily upon the Defense Logistics Agency (DLA), DoD’s largest logistics agency and the organization responsible for resourcing over 80 percent of the military’s retail and wholesale repair parts.<sup>65</sup> While DLA’s performance with wholesale parts, such as track pads and tires, has been historically favorable, low demand over time resulted in many legacy retail repair part suppliers reducing capacity, pursuing different or more profitable capacity, or exiting the military vehicle market completely.<sup>66</sup> To exacerbate the problem, TDPs for highly technical, yet low-demand parts, are often lost to posterity when the original supplier exits the market. This leaves DLA with little choice, but to reverse engineer the original part or to attempt to identify alternate sources of supply. Therefore, DLA should continually remind their exiting suppliers TDPs are a valuable asset that should be sold to firms specializing in supplying low demand repair parts to DoD. DLA should also encourage low-density parts suppliers to seek such opportunities. Unfortunately, when DLA loses TDPs to posterity it often results in spare parts provided at far higher cost, with exorbitant back-order times, and frequently outside of technical specifications for the system.

Despite DLA’s best efforts, operational readiness rates throughout DoD’s legacy ground vehicle fleets suffers, not only due to diminishing suppliers, but also due to increasing demand on aging fleets, poor unit forecasting, insufficient depot and unit-level parts inventories, and the cyclical, oftentimes unpredictable, funding environment throughout the DoD (See Appendix F, Tables 1 through 4). As a result, tactical units, and to lesser extent depots, often endure long lead times and extended customer wait times for Class IX repair parts critical to maintain the DoD’s military vehicle fleets. As Table 5 in Appendix F indicates, units routinely endure delays up to 24 months for some parts, and as demonstrated at ANAD, delays in ground program reset, often result from supply chain gaps.

Looking ahead to maintaining new programs such as the JLTV, Ground Mobility Vehicle (GMV), and MPF, DoD must consider a more effective system to supply its warfighters with much needed parts. Life-cycle sustainment must be included in the program at the earliest stages with contracts for replenishment repair parts included in the program, with or without TDP. Additionally, additive manufacturing is becoming an effective and inexpensive alternative to replace old parts no longer produced. Finally, DoD must reconsider the role DLA plays in life-cycle sustainment and investigate ways to improve supply performance, or allow other supply chain managers, such as OEMs, to compete with DLA for the right to supply parts for certain systems and commodities.

## **GOVERNMENT GOALS, ROLES, AND RECOMMENDATIONS**

Building upon the current conditions, challenges, and outlook for the TWV and CV markets, comparison to the European markets, and in conjunction with cross-cutting themes surfacing throughout industry, the study team chose a few strategic level topics for recommendations to the USG and DoD. Given the fiscal and political environments, recommendations provided account for resource constraints and political interactions among key stakeholders.

### **Export Sales and International Cooperation**

With respect to DoD's budget topline and cyclical demand for military vehicles, the USG must reform its arms export policies and international cooperation to bolster the U.S. DIB. Any reform would require significant Congressional involvement to consolidate efforts. The USG must continue with and augment ongoing export control reform by making the process more efficient and effective with a single oversight agency. Defense firms do not see the separate Commerce and State Department lists as being helpful as it is the same amount of work, just with two different agencies. The USG should revise export controls with what SECDEF Gates proposed as creating "a single primary export control licensing agency for both dual-use and munitions exports," a unified control list, single enforcement coordination agency, and a single integrated information technology system that would list sanctioned and denied parties in one database.<sup>67</sup>

Additionally, commodity items that are not truly sensitive and available on the open market should be removed from the US Munitions List and Commerce Control List. While some may oppose this idea due to the ability to potentially use the product for military force, U.S. defense firms see certain items as overly restricted by one or more USG agencies when the same item is sold internationally by a foreign firm. If U.S. firms are restricted from selling these items, foreign militaries will purchase them from other firms, thus bolstering another nation's economy and DIB.

Furthermore, the policy restricting the timing of international sales needs to be reviewed. For example, firms frequently state they would like to make their capabilities available for sale overseas earlier in the procurement run (i.e. during Low Rate Initial Production (LRIP), or during Operational Test and Evaluation (OT&E)). However, they are often forced to wait later until DoD decides to commence full rate production (FRP), or when DoD declares Full Operational Capability (FOC).<sup>68</sup> Speed to market means everything to firms, and waiting later often equates to lost sales opportunities for the U.S. DIB. Simply stated, domestic defense firms feel a foreign military should have the option to purchase a cleared military capability before the completion of testing, with the understanding they do so at their own risk.

In addition to allowing U.S. firms to sell defense products overseas, there is an opportunity to provide stability to U.S. firms by allowing them to manufacture land combat systems in foreign states. Many foreign partners seek to establish their own DIB and want to manufacture certain products, components, or vehicles within their own borders. This concept of requiring "offsets" forces a USG review of transfer of technology, IP, and manufacturing capabilities. While some may oppose the idea of establishing manufacturing in foreign states, there is precedence for partner states producing U.S. designed weapon systems. Given the robust oversight of international arms sales and key structural policies, it is feasible to allow defense firms to manufacture military vehicles or certain components overseas. Achieving a foreign market for U.S. products and establishing in-country manufacturing capability allows U.S. DIB firms to maintain a level market demand rather than

depend upon cyclical U.S. demand. Oftentimes, this level demand results in lower costs for the same product due to a larger production base.

Finally, the USG should consider opening the aperture for U.S. and foreign partnerships. As stated previously, some partnerships already occur, as with BAE and Iveco for the ACV competition. However, the partnership is somewhat disjointed, as Iveco owns the technical engineering behind the base vehicle, while BAE serves as the firm responsible to DoD for the ACV's manufacture and assembly. More technological sharing between defense firms or full mergers itself may prove to lower unit costs and increase platform performance, dependability and life-cycle sustainment in the long-run. Given the cap on military spending due to other budget requirements and the globalization of supply chains already, the USG would be prudent to facilitate these possibilities. Likewise, one concept DoD and the USG should consider is whether it encourages (mostly from a political viewpoint) a foreign manufacturer to supply a major component in a U.S. combat vehicle, a palatable idea if the foreign firm were to establish a manufacturing plant in the United States. An ancillary benefit of such a proposal would be spurring innovation and efficiency in the U.S. military vehicle market due to increased competition.

By revising arms export policies to allow U.S. firms to wholly partner with foreign firms or establish manufacturing capabilities inside foreign borders, the USG will strengthen the defense industry by countering cyclical DoD demand for defense products. Looking ahead to future market scenarios and continued austere budgets, the USG would benefit from foreign investments in the U.S. DIB rather than continue budget practices that pay high premiums to sustain minimal production, especially in the CV market.

### **Requirements, Innovation, and Procurement**

In addition to supporting industry export efforts, DoD must provide accurate and achievable design requirements to DIB firms to avoid acquisition failure given the high stakes environment of newer military vehicle contracts with advanced technological design and higher procurement costs. Recent successes in acquisition programs have been attributed to open communication between DoD and defense firms including the JLTV and ACV programs, where one-on-one conversations between firms and senior leaders in DoD resulted in weapons systems expected to meet or exceed threshold requirements during OT&E.<sup>69</sup> JLTV is intended to provide an affordable integrated package optimizing performance, payload capacity, and protection, while remaining light enough for easy transport. The interaction between the U.S. Army and USMC program offices and industry helped shape the revision of requirements to achieve an affordable and executable program. Additionally, the JLTV PM designed an acquisition strategy to optimize competition through design down-select for LRIP and FRP to control costs.

Furthermore, it is possible to pull more S&T advances out of industry. The highly competitive CV market should be exploited to DoD's advantage to the maximum extent possible by changing the way requirements are written. Instead of taking risk by writing threshold requirements to a high standard in the hope that industry can meet them, future requirements should be written so the acceptable threshold standard is lowered, thereby incentivizing industry to do more R&D on their own to position themselves with a greater advantage over their competitors. This change may spur unique innovation by industry once the aperture of what is acceptable is widened.

In addition to lowering thresholds, requirements should remain specific for each operational need rather than compiling multiple operational requirements on one vehicle. As an example, the U.S. Army, USMC, and even United States Air Force (USAF) do not need to outfit every unit with JLTVs designed to protect occupants from IEDs. DoD could easily continue the HMMWV life-cycle for general purpose TWV use while acquiring a number of JLTVs for use in anti-access areas. DoD must allow each Service to have its niche capability rather than roll all Service requirements into single programs, thereby increasing cost, decreasing performance, and subjecting the program to cancellation when a firm is not able to meet either cost or performance.

While DoD looks at future requirements, it must efficiently manage funding to support upgrades. In situations where money is tight, large organizations tend to centralize control of spending in order to ensure priorities are followed and waste is minimized to the greatest extent possible. Risky ventures must be closely scrutinized and balanced against immediate and mid-term requirements. As such, the U.S. Army should consider moving the planning and program for S&T from ASA(ALT) to G-8 to better synch and prioritize long-term S&T with near- and mid-term program R&D. Centralizing all S&T and procurement money for CVs under the G-8 might enable better synchronization of priorities and funding and timing between research, development and production efforts. The risk of centralization is that it is counter to everything the military believes in as it can stifle creative ideas while establishing group-think. However, given the current budget environment facing DoD, this risk should be acceptable as the alternative can lead to wasted funding or investment.

Additionally, the U.S. Army should consider a major realignment of RDECOM and its subordinates by moving these organizations out from under AMC. AMC is a 4-star command whose core mission is the sustainment of existing platforms, not the development of S&T. RDECOM might fit well under ARCIC, especially if ARCIC was removed from TRADOC. This course of action would have two benefits: it keeps ARCIC from directly influencing the requirement documents to the point they are unachievable, and it better synchronizes ARCIC's vision of future warfighting with a focus on what S&T can actually produce. Keeping ARCIC closely involved with near- and mid-term requirements runs the risk of capabilities-based requirements that overreach what industry can provide within the five to ten-year range. Removing ARCIC from TRADOC, and assigning the RDECOM community under them, would allow ARCIC and RDECOM to synchronize their focus on the long-term.

Finally, once sustainment requirements are provided and firms submit proposals, DoD must reconsider its initial LPTA acquisition practices—mostly for component and sub-component parts—and consider further the total cost of programs over the entire life-cycle of the vehicle. Purchasing the lowest priced component or part may in-turn lead to higher costs over the life of the program due to failing parts and lack of world-wide sustainment capabilities. Purchasing a higher priced, yet higher quality component or part, with an overall more robust sustainment package leads to lower life-cycle costs and increased readiness.

As DoD faces higher acquisition costs for more advanced ground vehicles to replace legacy vehicles to counter formidable adversaries, it cannot succumb to the same mistakes leading to program cancellations and the loss of millions of dollars. As such, DoD must effectively manage requirements and innovation in a way to ensure the success of future acquisition programs or face decreasing readiness rates and increased costs trying to maintain existing platforms to bridge the gap.

## Sustainment and Supply Chain Management

As DoD moves forward with new acquisition programs, it must bridge the gap by maintaining legacy systems at acceptable readiness rates to equip warfighters with needed military vehicles. DoD must implement prudent planning and funding to ensure DLA, the DIB, and the supply chain for military vehicles are postured to provide seamless and responsive support throughout the duration of each program's projected life. To this end, the study team recommends the following solutions and mitigation measures.

First, the USG must ensure contracts governing replacement parts, with or without applicable TDPs, are included as acquisition programs are developed and finalized. In addition, in conjunction with the demand reduction strategy, DoD must aggressively pursue additive manufacturing capability as an effective and inexpensive alternative to replace broken, unrepairable, unreplaceable parts, particularly for land combat systems.<sup>70</sup>

Next, assuming DLA continues to serve as the primary source for wholesale and retail parts, DoD should require individual Services to pay DLA in advance for at least a portion of projected parts forecasts, vice waiting until a valid requirement emerges to initiate a requisition process. While this change admittedly siphons some O&M funds in advance of actual requirements, it encourages the Services to dedicate appropriate time and analysis to formulate projections. Over time, this helps right-size inventories, decreases CV and customer wait time at depots and units, and results in cost efficiency.

Furthermore, DoD should implement a bi-annual, by-Service stockage list review, whereby each department reviews repair part requirements stocked by DLA against demand-supported items compiled over the last three years. As lower-demand items process out of DLA's warehouses for storage, Services must refrain from reordering those items at full cost until it is confirmed parts are not already available in Disposition Services for near-immediate reissue at minimal cost.

Additionally, DoD should consider a policy revision to enable DLA, each of the Services, and all the depots and arsenals to purchase critical, long-lead time parts directly from the prime vendor, OEM, or primary supplier vice requiring purchases through DLA. Doing so improves responsiveness, establishes a legitimate and reliable demand signal for industry, and increases competition and component quality.

Along with a new policy, DoD should dedicate resources to reconstitute the supply network so 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> tier suppliers are incentivized to remain in the market and meet current and projected demand, now and into the future. Given DoD's extension of the M1 Abrams and the Bradley Family of Vehicles (BFV) life-cycles through 2035, readiness rates simply cannot get any better without action and focus. Furthermore, as maintainers throughout all Services execute controlled exchange with increasing frequency, countless man hours continue to be wasted as Soldiers, Sailors, Airmen, and Marines attempt to circumvent and compensate for gaps in the existing supply chain.

With respect to maintaining a sufficient supply of parts, DoD should consider "renting" TDPs from firms for the duration of a platform's projected life-cycle. While OEMs would continue to serve as primary parts suppliers, in the event they prematurely exit the market or are otherwise unable to meet demand, this practice would enable the USG to provide another manufacturer the TDP to legally generate critical parts, thereby ensuring DoD's efforts to employ, repair, reset, and/or recapitalize its LSC platforms continues without significant delay or disruption.

Finally, DoD should consider a common engine and transmission, a full-up power pack (FUPP), for most, if not all CV platforms. Doing so dramatically increases market demand for a narrower selection of parts and decreases uncommon stockage objectives at units and depots, thereby reducing range complexity within the supply chain. Like the common platform approach, narrowing the parts menu across the joint force increases the likelihood suppliers who specialize in the thousands of components beyond the engine and transmission will be able to remain in business and serve as reliable, long-term sources of supply.

These recommendations, even if solely implemented, will reduce challenges facing logisticians in all Services as they battle aging equipment and obsolete parts while striving to maintain readiness rates. Without an overhaul of sustainment and supply chain practices, DoD stands to see a rise in equipment failures, a decline in readiness levels, together placing the men and women fighting U.S. wars at higher risk.

### **Maintaining the Combat Vehicle Defense Industrial Base**

As DoD focuses on sustaining its legacy fleet, it must continue to maintain the DIB as very few firms have the industrial knowledge, capital equipment, resources, and interest in manufacturing CVs, especially tracked CVs. Given the requirement to maintain the combat edge our CV's provide against formidable enemies, the USG and DoD must seek more cost-effective and efficient ways in which firms remain viable to produce the next CV without committing exorbitant amounts of precious DoD funds. As such, the DoD must balance all the tradeoffs involved in maintaining a robust industrial base for CVs. One potential rebalance is to examine the duplicative capacity between the public and private sectors. While it is true many in DoD and Congress argue the duplication ensures continuous supply in the case of a natural disaster or attack at one location, current budget constraints do not offer the luxury of funding multiple production locations during times of low demand. Alternative policies may be prudent, but only after careful examination of risk tolerance. While DoD strives to maintain a robust industry, some greater assumption of risk may be warranted to garner more of an affordable cost to the taxpayer, especially during times of low demand or fiscal austerity.

In regards to the CV industry, DoD generally accepts a timeline of more than a year to establish a heavy manufacturing production line. Without incentives to modernize or without competition in the CV markets, DoD is enabling its defense base to remain stagnant in comparison to the innovation seen in the European defense market. Worse yet, DoD's main battle tank may be surpassed by near-peer threat capabilities, shown by the emergence of the technologically advanced Russian Armata. Telling enough, continued stagnation is jeopardizing the asymmetry U.S. CVs provide and leads to obsolescence on the battlefield, especially against near-peers. Without innovation, the Abrams MBT could become CV's version of the HMMWV in the next war.

As such, there are several recommendations for the USG and DoD to maintain a robust industrial base for CVs. The first recommendation is to conduct an independent study of the U.S. Army's CV manufacturing, recapitalization, and reset capabilities, as well as analyze the capabilities, cost, and risks associated with maintaining duplicative capacities across Government Owned/Government Operated (GOGO), GOCO, and Contractor Owned/Contractor Operated (COCO) facilities. Certainly, a holistic approach across the entire CV defense base is warranted.

The second recommendation is for DoD to look for ways to introduce competition into the CV market space. For example, the current setup within JSMC has one contractor overseeing a government owned facility for its operations. Introducing an independent contractor to oversee the facility could allow other firms to use the facility and challenge the incumbent for space and efficiencies—benefiting the USG by reducing overhead and capital improvement costs. Additionally, with multiple lines from joint programs operating in JSMC, it would truly become “joint.” Otherwise, the Army should change the JSMC back to the Lima Army Tank Plant and convert it into an Army Working Capital Fund activity. The U.S. Army is already paying for the installation and its services, just through different means. Regardless of the options, the intent is to keep the current work force in Lima, Ohio, while removing GDLS from overseeing the operations of the facility. Obviously, there are multiple options to weigh, but seeking greater competition within the CV market can definitely drive more innovation and lower cost to the taxpayer.

By implementing these solutions, the USG may be able to save costs associated with maintaining the CV DIB at a time when U.S. demand for MBTs and IFVs remains low. Maintaining the status quo of paying a high premium for limited manufacturing capability only serves to consume precious budget resources during periods of fiscal austerity and increasing the cost per unit of advanced CVs.

## CONCLUSION

The Class of 2017 LCS Industry Study team analyzed the behavior of the markets and industry participants associated with ground military vehicles, as a representative industry critical to national security. Using the tools garnered throughout the Program of Study for land combat systems, the study team identified common themes and trends associated with the industry with respect to the domestic TWV and CV markets and current conditions, challenges, and future outlooks. In addition, the study team provided observations and comparisons of the European market based upon a selected cross-section of European firms. Based upon the domestic and international analysis, the study team identified cross-cutting themes including export sales opportunities and foreign partnerships, emerging threats and investing in the future, requirements generation, and sustainment and supply chain management. Finally, the study team proposed some key recommendations for the USG and DoD to address stated challenges.

As the military vehicle industry varies from a monopoly in the CV market to a competitive oligopoly in the TWV market, USG and DoD involvement in the industry varies with respect to the ability of firms to weather cyclical demand along with inherent technological capability and expertise to produce TWVs and CVs for DoD. Overall, the complexity of manufacturing and sustaining CVs, complicated by a limited number of firms with the inherent knowledge to do so, forces the USG and DoD to increase oversight and involvement in that market to maintain the capacity to meet demand. On the other hand, the production of TWVs, which shares commonality with commercial vehicles, requires less direct USG and DoD involvement with several firms able to meet demand when needed.

In comparison to the U.S. market, the European market has defense firms adjusting strategies to meet demand and remain competitive globally. One key difference between the U.S. and European markets, however, is the limited involvement of European governments in providing monetary support to their firms. This lack of funding forced most European firms to innovate or partner to maintain market share. As these firms become more competitive, U.S.

firms will face stiffer competition unless US government policy is more effective in promoting exports and trans-Atlantic partnerships.

With a lack of innovation, restricted access to global demand, and shifting requirements, DoD cancelled several follow-on military vehicle programs. As such, DoD is forced to maintain ageing equipment with some difficulties in securing replacement parts. These headwinds, along with a rising European industrial base and an advanced Russian MBT, threaten to challenge the U.S. role in supplying competitive combat capabilities to DoD and partner nations. Therefore, the study team provided several recommendations.

The USG should look to overhaul arms export policies by placing one USG entity in charge of export controls, and possibly increasing joint ventures between U.S. and foreign defense firms. Additionally, DoD must realign S&T practices by centralizing requirements and funding under one command. Next, DoD and Congress should cease to require joint programs to meet multiple Service needs, which results in increased product cost and risks cancellation. Furthermore, DoD should analyze how it utilizes DLA with respect to commodity parts versus parts in low demand with specific capabilities. Finally, DoD and Congress should analyze the duplicative capabilities across the CV base and investigate the potential of turning JSMC over to an independent contractor.

The United States depends upon its ground military vehicles to win its wars, secure global peace and defend against rising governments wishing to undermine U.S. power projection. However, budget reductions, failed attempts to acquire a newer generation of military vehicles, and the desire to consolidate requirements across Services are jeopardizing the U.S. military's asymmetrical advantage. If not specifically addressed, it will force the men and women of the U.S. and partner militaries to fight future wars with ever decreasing ground combat capabilities. The USG and DoD must take immediate action to invigorate this very important industrial base to secure the future of democracy and U.S. wartime capabilities.

## Appendix A: Acronyms

AAV	Amphibious Assault Vehicle
ABCT	Armored Brigade Combat Team
ACE	Armored Combat Earthmover
ACV	Amphibious Combat Vehicle
AECA	Arms Export Control ACT
AMG	American Motors General
AMPV	Armored Multi-Purpose Vehicle
ANAD	Anniston Army Depot
AWCF	Army Working Capital Fund
BAE	British Aerospace Engineering Systems. Note: this paper infers BAE to refer to “BAE Systems Inc.” the U.S. based subsidiary.
BCA	Budget Control Act
BBP	Better Buying Power
BFV	Bradley Fighting Vehicle (M2A3, M3A3)
BRAC	Base Realignment and Closure
COCO	Contractor Owned Contractor Operated
COCOM	Combatant Commander
CONUS	Continental United States
CV	Combat Vehicle
DCAA	Defense Contract Audit Agency
DCMA	Defense Contracting Management Agency
DCS	Direct Commercial Sales
DIB	Defense Industrial Base
DLA	Defense Logistics Agency
DLH	Direct Labor Hour
DoD	Department of Defense
DoJ	Department of Justice
DVH	Double V-Hull
EU	European Union
EDA	European Defense Agency
EMD	Engineering Manufacturing Development
FAR	Federal Acquisition Regulations
FCS	Future Combat System
FMS	Foreign Military Sales
FMTV	Family of Medium Tactical Vehicles
FY	Fiscal Year
FYDP	Future Years Defense Program
GCS	Ground Combat Systems
GCV	Ground Combat Vehicle
GDLS	General Dynamics Land Systems
GOCO	Government Owned Contractor Operated

GOGO	Government Owned Government Operated
GMV	Ground Mobility Vehicle
HEMTT	Heavy Expanded Mobility Tactical Truck
HET	Heavy Equipment Transporter
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IR&D	Independent Research and Development
IED	Improvised Explosive Device
IFV	Infantry Fighting Vehicle
ITAR	International Traffic in Arms Regulation
JLTV	Joint Light Tactical Vehicle
JSMC	Joint Systems Manufacturing Center
KMW	Krauss-Maffei Wegmaan
LAV	Light Armored Vehicles
LCS	Land Combat Systems
LVSR	Logistical Vehicle System Replacement
MBT	Main Battle Tank
MCoE	Maneuver Center of Excellence
MLRS	Multiple Launch Rocket System
MPC	Marine Personnel Carrier
MPF	Mobile Protected Firepower
MRAP	Mine Resistant Ambush Protected
M-ATV	MRAP All-Terrain Vehicle
MSR	Minimum Sustainment Rate
MTV	Medium Tactical Vehicle
NATO	North Atlantic Treaty Organization
NSS	National Security Strategy
OEM	Original Equipment Manufacturer
OIB	Organic Industrial Base
O&M	Operations & Maintenance
P3	Public-Private Partnership
PB	Presidential Budget
PEO	Program Executive Office
PIM	Paladin Integrated Management
PLS	Palletized Load System
PM	Program Manager
PMO	Program Manager Office
PPBE	Planning, Programming, Budget, and Execution
R&D	Research & Development
SLEP	Service Life Extension Program
S&T	Science and Technology
TACOM	Tank-Automotive & Armaments Command
TDP	Technical Data Package
TRADOC	Army Training and Doctrine Command
TWI	Training With Industry
TWV	Tactical Wheeled Vehicle

ULCV	Ultra-Light Combat Vehicle
ULSD	Ultra-Low Sulfur Diesel
USAF	United States Air Force
USD (AT&L)	Under Secretary for Defense for Acquisition, Technology, and Logistics
USMC	United States Marine Corps
WSARA	Weapon Systems Acquisition Reform

### Appendix B – Land Combat Systems Vehicle Classes

<b>Tactical Wheeled Vehicles (TWV)</b>	<b>Combat Vehicles (CV)</b>
<b>Light Trucks</b> High Mobility Multipurpose Wheeled Vehicles (HMMWV) USSOCOM Ground Mobility Vehicle (GMV) Joint Light Tactical Vehicle (JLTV)	<b>Armored Personnel Carriers (APC)</b> Stryker M113
<b>Medium Trucks</b> Family of Medium Tactical Vehicles (FMTV) Medium Tactical Vehicle Replacement (MTVR)	<b>Amphibious Assault Vehicles (AAV)</b> AAV Amphibious Assault Expeditionary Vehicle (AEV)
<b>Heavy Trucks</b> Heavy Expanded Mobility Tactical Trucks (HEMTT) Palletized Loading System (PLS) Heavy Equipment Transporter (HET)	<b>Self-Propelled Artillery (SP)</b> M-109
<b>Mine Resistant Ambush Protected (MRAP)</b> Caiman (4x4) (6x6) RG-31, 33 (4x4) (6x6) Cougar (4x4) (6x6) MaxxPro (4x4) MATV (4x4)	<b>Infantry Fighting Vehicles (IFV)</b> M-2 Bradley <b>Main Battle Tanks (MBT)</b> M1 Abrams

### Appendix C – Tactical Wheeled Vehicles

#### TACTICAL WHEELED VEHICLES (LIGHT TRUCKS)



Highly Mobile Multi-Wheeled Vehicle (HMMWV)



Ground Mobility Vehicle 1.1 (GMV 1.1)



Joint Light Tactical Vehicle (JLTV)

#### TACTICAL WHEELED VEHICLES (MEDIUM TRUCKS)



Family of Medium Tactical Vehicle (FMTV)



Medium Tactical Vehicle Replacement (MTVR)

#### TACTICAL WHEELED VEHICLES (HEAVY TRUCKS)



Heavy Expanded Mobility Tactical Truck (HEMTT)



Heavy Equipment Transporter (HET)

PROTECTED VEHICLES (4X4)



Caiman



RG-31



Cougar



MRAP All Terrain Vehicle (M-ATV)

PROTECTED VEHICLES (6X6)



Caiman



RG-33



Cougar

### Appendix D - Combat Vehicles

#### COMBAT VEHICLES (CV) INFANTRY FIGHTING VEHICLE (IFV) / MAIN BATTLE TANK (MBT)



M2 Bradley



M1 Abrams

#### COMBAT VEHICLES (CV) ARMORED PERSONNEL CARRIERS (APC)



M113



Stryker

#### AMPHIBIOUS VEHICLES



AAV-7



Amphibious Combat Vehicle (ACV) 1.1 EMD Prototype



Amphibious Combat Vehicle (ACV) 1.1 EMD Prototype

### Appendix E - Figures

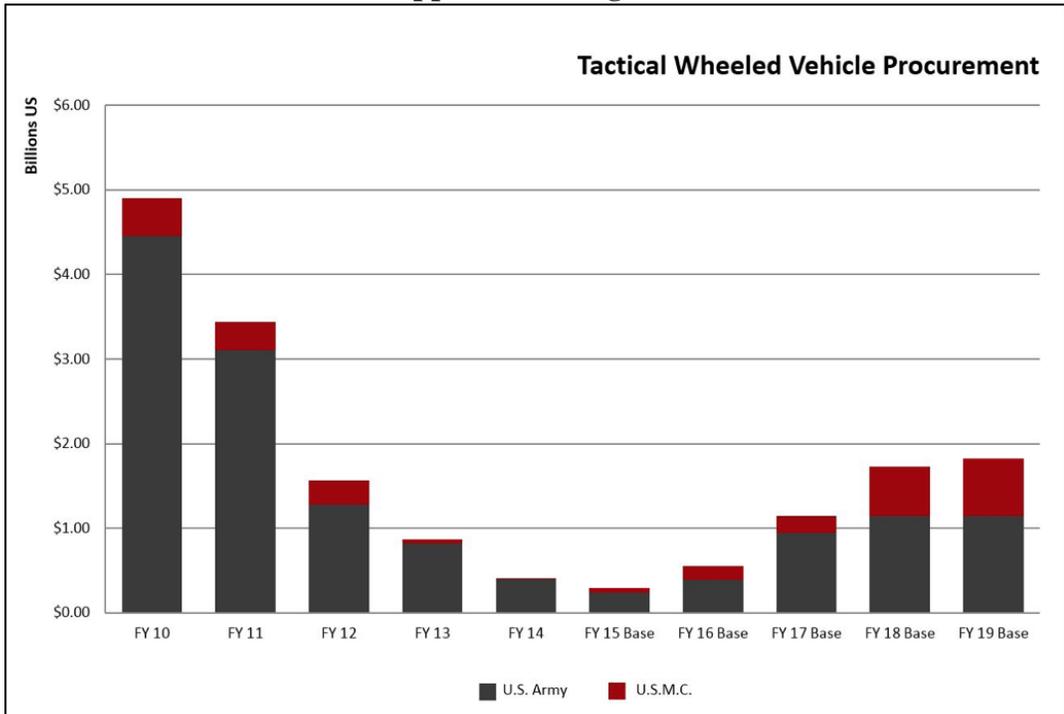
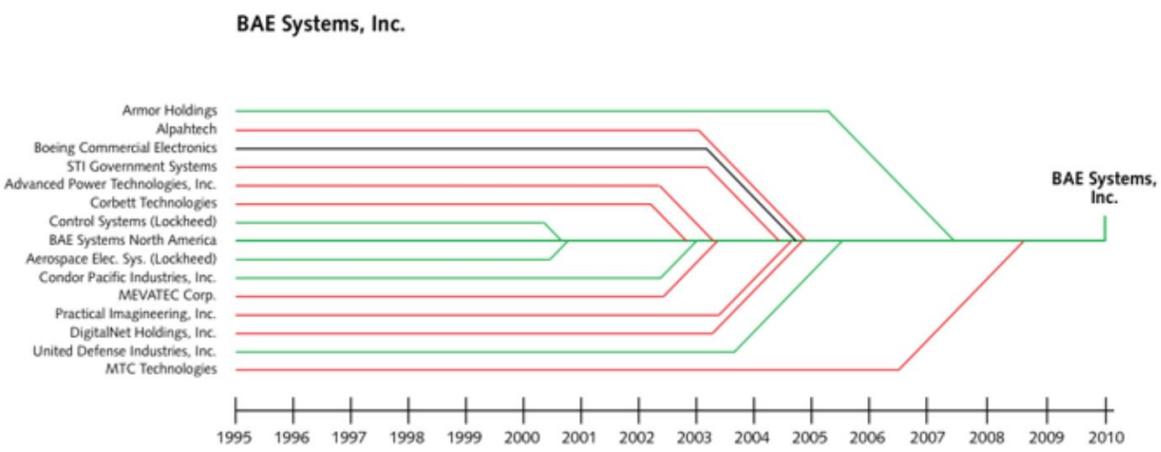


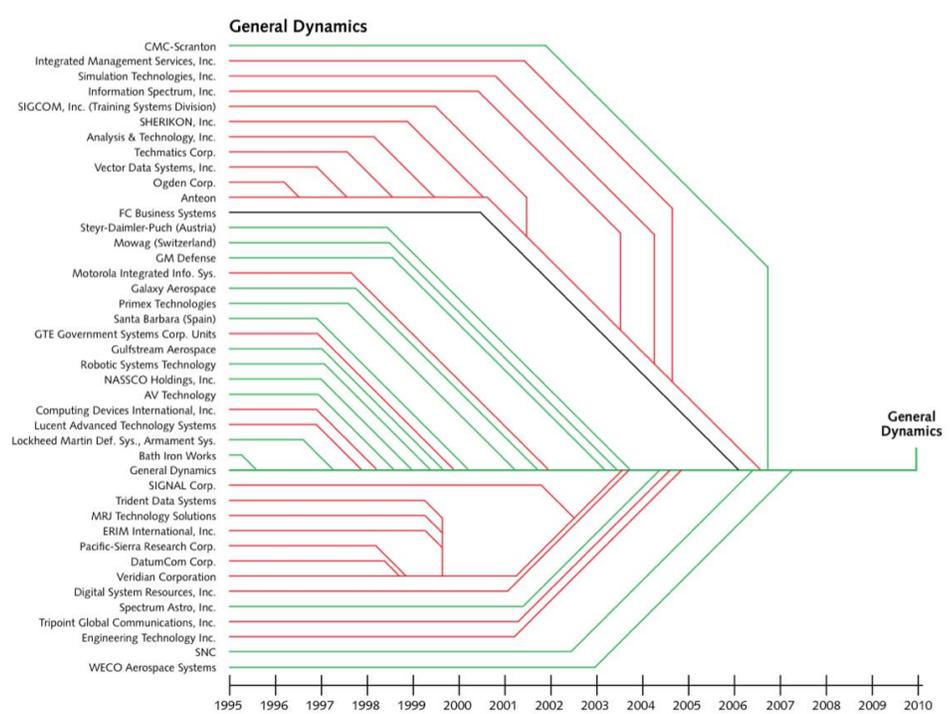
Figure 1. Bathtub Defense Industrial Base Market for Tactical Wheeled Vehicles<sup>71</sup>



Sources: DM&A, Washington Technology, various company reports, and analysis by CSIS Defense Industrial Initiatives Group.

Key: Federal services companies: —; defense hardware companies: —; commercial IT: —

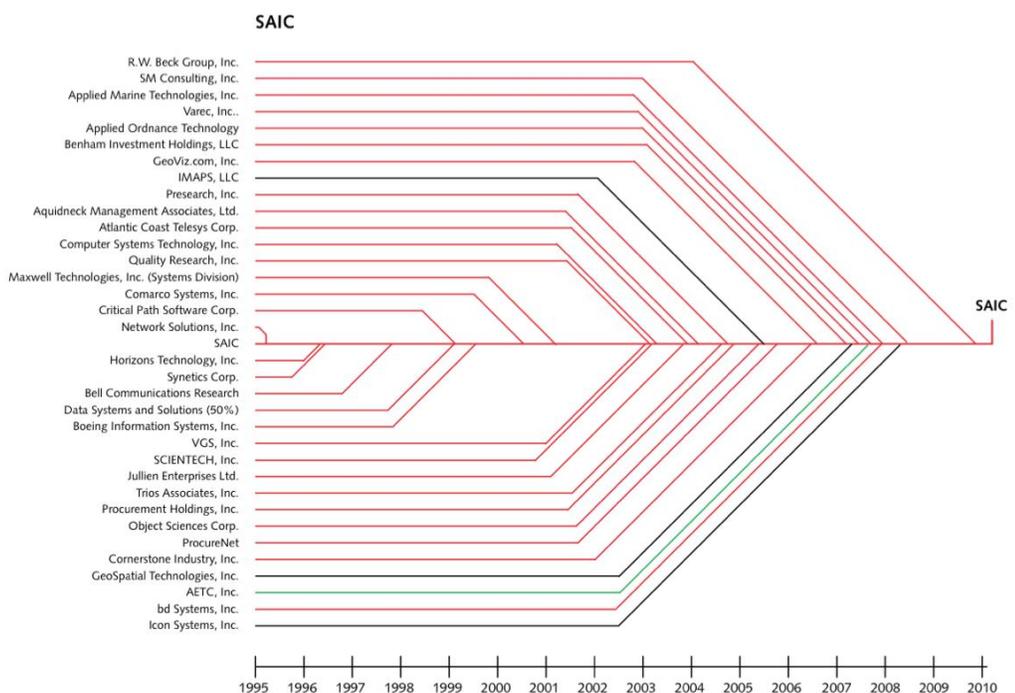
Figure 2. BAE Consolidation



Sources: DM&A, *Washington Technology*, various company reports, and analysis by CSIS Defense Industrial Initiatives Group.

Key: Federal services companies: —; defense hardware companies: —; commercial IT: —

Figure 3. General Dynamics Consolidation



Sources: DM&A, *Washington Technology*, various company reports, and analysis by CSIS Defense Industrial Initiatives Group.

Key: Federal services companies: —; defense hardware companies: —; commercial IT: —

Figure 4. SAIC Consolidation

	US	Europe
<b>Tanks</b>	M1 Series (GDLS)	Leopard II (KMW, Germany) Challenger II (BAE/Vickers, UK) LeClerc (Nexter, France) Ariete (Oto Melara-Iveco, Italy) Altay (Otocar/Hyundai, Turkey)
<b>Tracked Infantry Fighting Vehicles</b>	Bradley (BAE) Amphibious Assault Vehicle (BAE)	Puma (KMW & Rheinmetall, German) ASCOD (Steyr, Austria; Santa Barbara, Spain) Dardo (Oto Melara-Iveco, Italy) Ajax Scout Vehicle (GDUK, UK) Warrior (BAE, UK) CV-90 (BAE Hägglunds, Sweden) BMP-3 (Rosoboron Export, Russia)
<b>Wheeled Combat Vehicles</b>	Stryker (Piranha III+) (GDLS) LAV (Piranha I+) (GDLS) ACV 1.1 (TBD)	Pandur (GDELS Steyr, Austria) Piranha (GDELS Mowag, Swiss) AMV (Patria, Finland) Centaro/Freccia (Oto Melara-Iveco, Italy) Boxer (KMW/Rheinmetall, Germany) VBCI (Nexter, France) Scorpion (Nexter-Renault, France) Fuchs (Rheinmetall) PARS (FNSS/GPV, Turkey)

71

Figure 5. European Defense Industrial Base in Comparison to United States

### Europe -- Land Combat Systems Consolidation

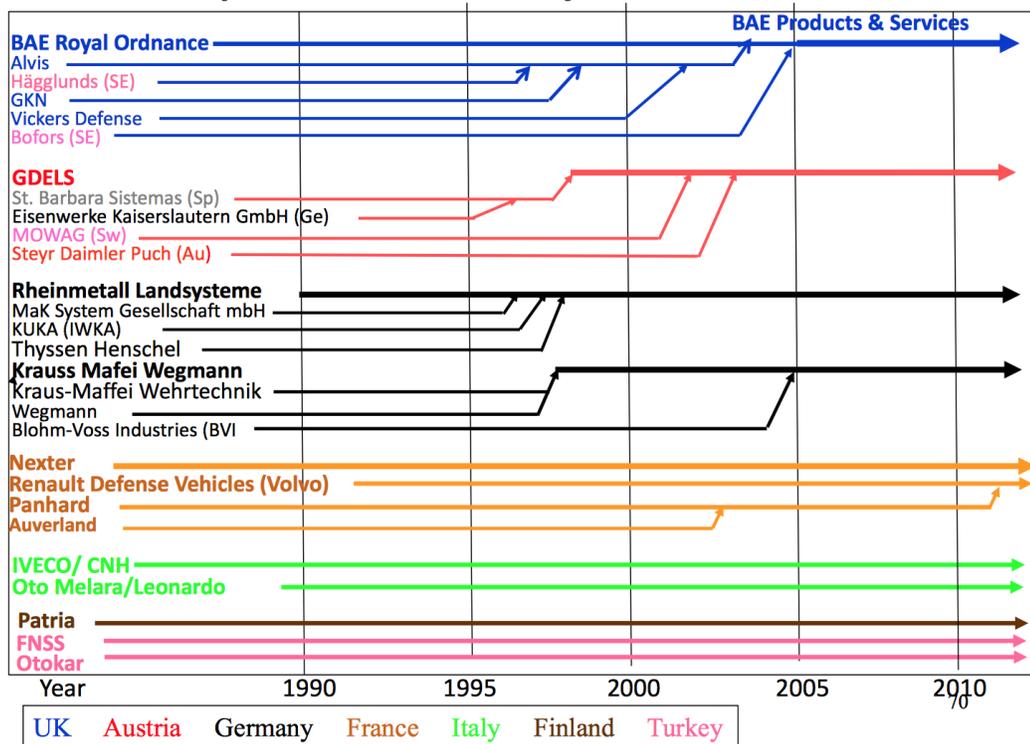


Figure 6. European Defense Industrial Base Consolidation

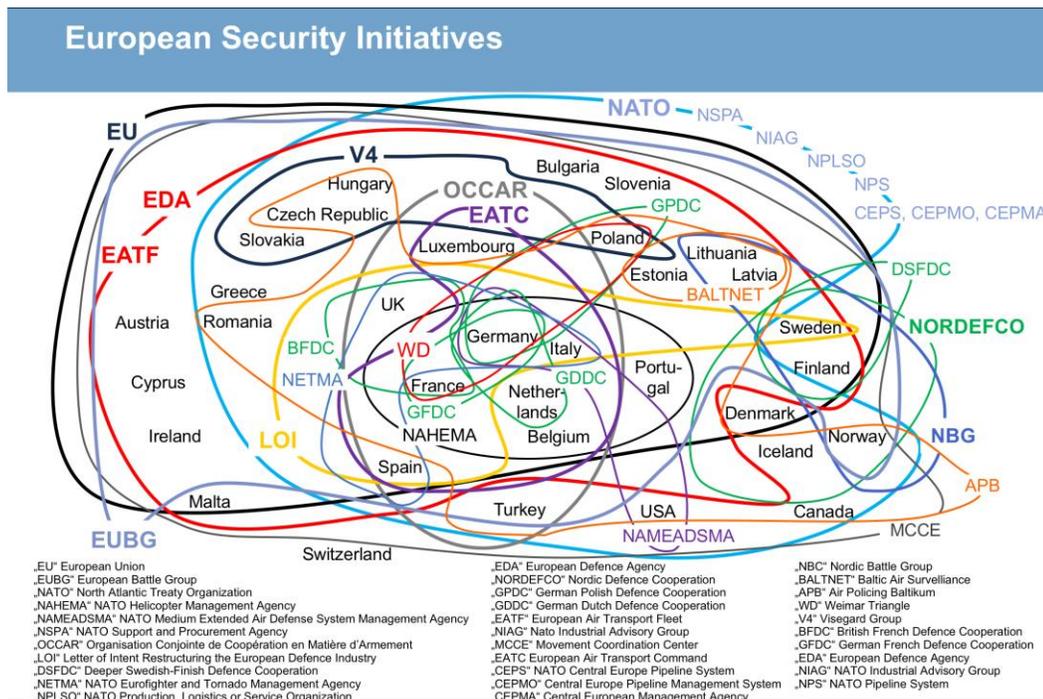
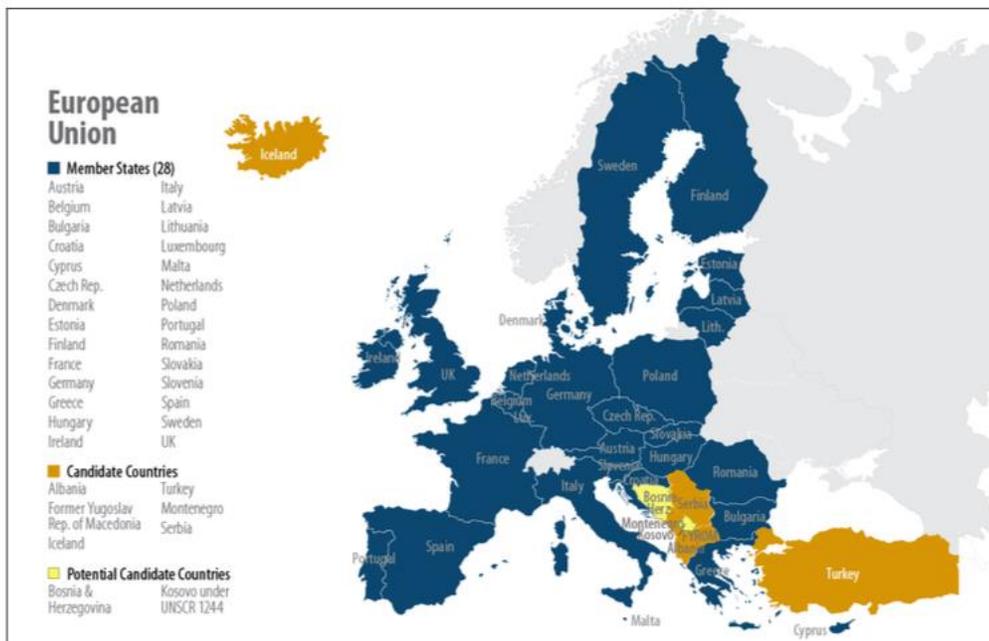


Figure 7. European Security Initiatives<sup>72</sup>



**Source:** Delegation of the European Union to the United States, "On the Path to EU Membership: The EU Enlargement Process," *EU Insight*, December 2010; adapted and updated by CRS.

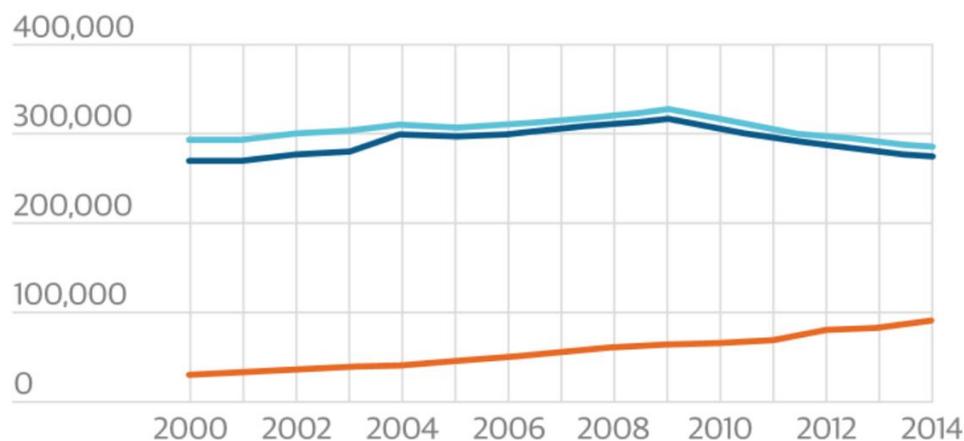
**Note:** Although the EU continues to recognize Iceland as a candidate country, accession negotiations have been on hold since May 2013. In March 2015, Iceland requested that it should not be considered a candidate for EU membership, but did not formally withdraw its application.

Figure 8. European Union Members

## Military expenditure of Russia, EU and Nato Europe

Constant (2001) US\$m

Russia | EU | Nato Europe



Guardian graphic

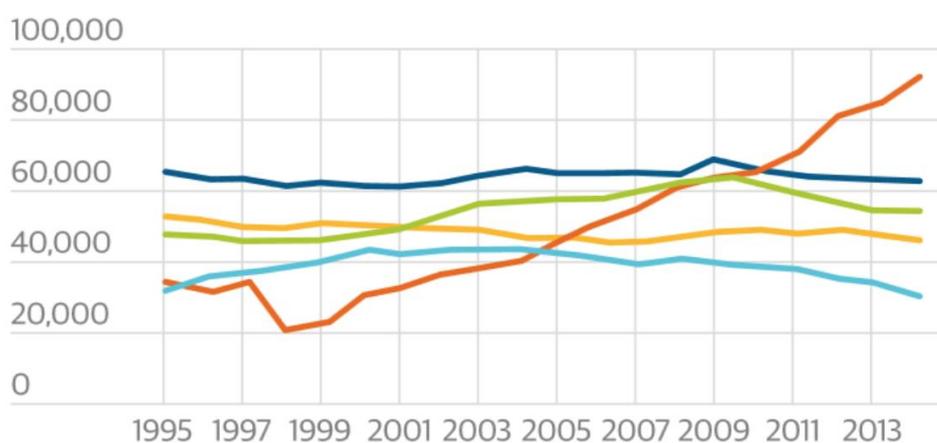
Source: Sipri

Figure 9. Military Expenditure of Russia, EU and NATO Europe

## Military expenditure of Russia and Western Europe

Constant (2001) US\$m

France | Germany | Italy | Russia | UK



Guardian graphic

Source: Sipri

Figure 10. Military Expenditure of Russia and Western Europe

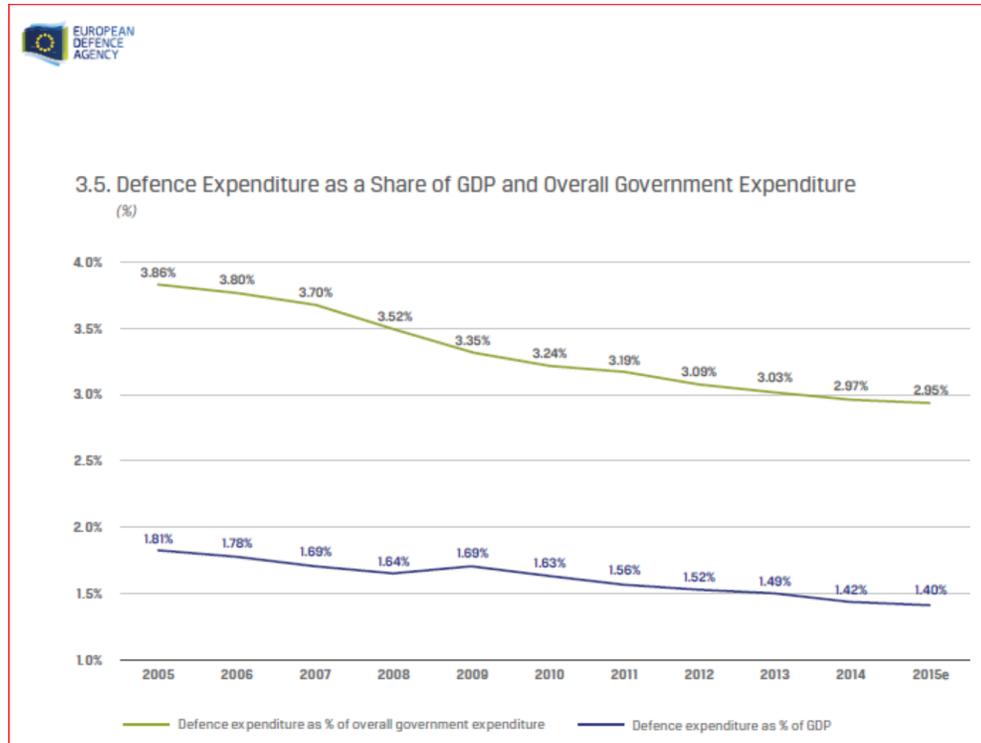


Figure 11. Defence Expenditure as a Share of GDP and Overall Government Expenditure

## Appendix F – Tables

### Table 1: M1A1 Fully Mission Capable Rates (2016)

<i>Reporting Period</i>	<i>1QTR/CY16</i>	<i>2QTR/CY16</i>	<i>3QTR/CY16</i>	<i>4QTR/CY16</i>
<b>Percentage</b>	73.5	84.8	80.6	74.1

Note: Based on a fleet density of **407 platforms** distributed throughout Active and Reserve formations.

### Table 2: M1A2 Fully Mission Capable Rates (2016)

<i>Reporting Period</i>	<i>1QTR/CY16</i>	<i>2QTR/CY16</i>	<i>3QTR/CY16</i>	<i>4QTR/CY16</i>
<b>Percentage</b>	83.2	84.1	84.1	80.5

Note: Based on a fleet density of **1,265 platforms** distributed throughout Active and Reserve formations.

### Table 3: Bradley Fighting Vehicle Fully Mission Capable Rates (2016)

<i>Reporting Period</i>	<i>1QTR/CY16</i>	<i>2QTR/CY16</i>	<i>3QTR/CY16</i>	<i>4QTR/CY16</i>
<b>Percentage</b>	86.9	90.3	87.1	86.2

Note: Based on a fleet density of **630 platforms** distributed throughout Active and Reserve formations.

### Table 4: M109A6 Paladin Fully Mission Capable Rates (2016)

<i>Reporting Period</i>	<i>1QTR/CY16</i>	<i>2QTR/CY16</i>	<i>3QTR/CY16</i>	<i>4QTR/CY16</i>
<b>Percentage</b>	86.6	85.9	82.5	75.2

Note: Based on a fleet density of **443 pieces** distributed throughout Active and Reserve formations.

**Table 5: Low Demand, Low Profit, Long Lead Time Parts Sample**

Part	Platform	Quantity Required	Quantity On-Hand (Depot + Field)	Remarks
DECU	M1A1	400	158	Procurement effort ongoing since 2014. Cooperation between DLA, Honeywell, and multiple agencies indicate earliest delivery in 3QTR/FY17.
Tension Device, Track	M1A1	652	0	Emergency purchase for 558 awarded to Global Defense in July 2016, with deliveries expected in May 2017.
A6 Circuit Card Assembly	M1A2	526	18	After substantial contract delay, contractor's Request for Deviation from the TDP was approved; delivery begins March 2017 at a rate of 35 per month
ICDU Switchboard	M1A2	357	126	Low vendor production capacity (10 per month), exacerbated by obsolescence issues with separate spare parts. Unless GDLS increases capacity, earliest get well date (assuming no additional requirements) is December 2019.
HPDU	M1A2	770	16	546 each obligated and due in November 2017. Lack of repairable HPDUs in system (units are retaining). Linked to A6 circuit card shortage (critical HPDU part).
Box Magazine, Ammunition	BFV	34	8	Low demand item, insufficient interest by industry in contract participation. Fabrication failed at Watervilet Arsenal; fabrication possible at Rock Island, but for a minimum of 1000 each. As of DEC 2016, item manager awarded a contract to a supplier and has arranged for the TDP to be sent to Watervilet to enable future fabrications. Initial deliveries expected no earlier than September 2017.
PDCU	M109A6	81	12	Paladin Digital Computer Unit: shortages resultant of contract delays and inability to maintain adequate assets on hand to enable timely repair and return.

## ENDNOTES

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