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LAND COMBAT SYSTEMS (LCS) 2016

ABSTRACT: The Land Combat Systems (LCS) industry is critical to the national security of the United States because it provides the very means by which American ground forces (Army and Marines primarily) fight and win our nation's wars. The US established itself as a world leader in this industry as it implemented the second offset but has made only incremental upgrades to that fleet over the past decades. To maintain parity and reclaim a degree of technological advantage among ground forces around the world, the United States must husband its resources carefully and develop thoughtful strategies to sustain the LCS industrial base, develop new systems or upgrades that provide the right mix of capabilities to accomplish assigned missions, and field them to the force.

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Industry Study Outreach and Field Study

On Campus Presenters:
BAE Combat Vehicles, Sterling Heights, MI
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Field Studies – Domestic:
Aberdeen Test Center, Aberdeen, MD
Allison Transmission, Indianapolis, 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, Sterling Heights, MI
Joint Systems Manufacturing Center, Lima, OH
PEO Ground Systems, Sterling Heights, MI
Tank Automotive Research, Development and Engineering Center, Sterling Heights, MI
US Marine Corps Program Management, Quantico, VA

Field Studies – International:
Fiat Test Track, Balocco, Italy
General Dynamics Land Systems Canada, London, Canada
Iveco Defense Vehicles, Bolzano, Italy
Krauss-Maffei Wegmann (KMW), Munich, Germany
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LAND COMBAT SYSTEMS 2016

Despite two decades of failed and cancelled attempts to field a new generation of combat vehicles, the Land Combat System (LCS) industry continues to provide the Army and Marine Corps with military vehicles, everything from trucks to tanks, with the lethality, mobility, and survivability necessary to win on the modern battlefield. But, the combination of years fighting insurgencies in Iraq and Afghanistan, the 2008 recession followed by slow global recovery, and unstable, often overreaching requirements, have inhibited LCS innovation to a series of limited upgrades and rebuilds on aging systems. This ability to successfully upgrade systems is at the same time a testament to the quality of those legacy systems, an indictment of vehicle acquisition programs, and an indicator of how elusive leap-ahead capabilities are among Land Combat Systems. To maintain parity and reclaim a degree of technological advantage among ground forces around the world, the United States (US) must husband its resources carefully and develop thoughtful strategies to sustain the LCS industrial base, develop new systems or upgrades that provide the right mix of capabilities to accomplish assigned missions, and field them to the force.

The LCS industry provides a wide and diverse spectrum of vehicles from trucks to protected vehicles to main battle tanks that offer an excellent mechanism for examining the Defense Industrial Base (DIB). The following pages contain an overview of the American LCS industry and an analysis of its constituent markets. It explores the more salient issues identified in conducting this research, which were drawn largely from primary sources, by visiting and talking to a variety of participants in the industry—representatives from the primary consumers of the industry the US Army (USA) and US Marine Corps (USMC), leadership from depots and test facilities, and the firms that drive the industry both in the US and in Europe. The paper ends by offering a handful of overarching conclusions from our study, as well as recommendations for how both government and business might better address the needs of both producers and consumers within the industry.

The LCS industry covers a spectrum of vehicle system capabilities that range from relatively simple, light trucks, from multiple, commercial-military, industry vendors to the most complex main battle tanks from a single, military-specific, industry vendor. There are three major classes of LCS: Tactical Wheeled Vehicles (TWV), Protected Vehicles (PV), and Combat Vehicles (CV). At the lower end, TWVs are less expensive and leverage commercially available components and manufacturing. The tracked vehicles, at the higher, more complex end of the spectrum, are high-cost vehicles that use military-specific components and technologies from a domestic dual monopoly vendor base (See Appendix B, LCS Vehicle Classes). Because many of the capabilities of Protected Vehicles have largely migrated to TWVs, this study did not address them as a separate class of vehicles. Instead, for this study they are subsumed under TWVs.

The LCS industry supplies more than newly built vehicles and consist of more than the major firms -- the primes -- that assemble them. The industry includes a network of first tier suppliers of major assemblies, components and parts and second and lower tier suppliers that feed parts and materials used by first tier suppliers. It also encompasses a base of depots and arsenals organic to the Department of Defense (DoD). Together the industry provides new vehicles as well as life cycle support, from the supply

of consumable and repairable parts used in basic maintenance to more involved processes like upgrades, which are modifications that result in improved performance and capability, and recapitalizations, which includes the overhaul, repair, and parts replacement necessary to restore vehicles to an original, zero miles condition.

THE LCS INDUSTRY IN CONTEXT

In the years following the 1991 Persian Gulf War, military force structure and procurement accounts shrank considerably. Indeed, this procurement holiday persisted throughout the Clinton administration as the country reaped the so-called peace dividend. But once it became embroiled in the conflicts in Iraq and Afghanistan, the US spent record amounts on TWVs, PVs, and CVs. From 2003 through 2007, the Department of Defense (DoD) spent an average of $6B on all three classes. Funding rapidly increased to $18B in 2007 and then reached a high of $27B in 2008. From 2009 through 2010, funding leveled out at $17B followed by a linear ramp down from $12B to $4B between 2011–2013 (See Appendix C for details). At the end of the conflict, Congress slashed the DoD budget through the Budget Control Act of 2011, resulting in a drastic downturn in procurement that several firms bemoaned as a "bathtub," one they hoped to climb out of in coming years.[1] In the absence of domestic demand, these firms are increasingly turning to foreign markets for future sales; indeed, some firms estimated that exports accounted for 50% or more of planned work.

The downturn in defense spending on military vehicles has been driven by more than just declining demand as wars in Iraq and Afghanistan wound down, rather it evolved rapidly within a larger and more turbulent economic context. The Great Recession of 2008-2009 led to unemployment above 10% and plummeting property values, which caused outlays for unemployment other support programs to spike just as revenues were in free fall. This meant there would be fewer dollars for future defense spending, a situation made worse by the deficit spending on bailouts and the so-called stimulus package. Since then, while unemployment has dropped, the economy as a whole has experienced "stable but grinding growth."[2] For the LCS industry the overall improvement is offset by two significant factors. First, the dollar has strengthened, making US exports of military vehicles even less affordable. Second, many buyers were hurt by slower global recovery from the Great Recession and (especially among Middle East and North Africa (MENA) countries) record low oil prices. Though oil prices have risen from their record low of $25 per barrel, even at $40 per barrel, Saudi Arabia and Gulf allies can expect a $300 billion drop in 2016 revenues and decreased buying power in the future.[3]

The geostrategic environment continues to evolve and place new demands on the LCS industry. Even as the industry responded to demand for protected vehicles to support more than a decade of war in Iraq and Afghanistan, new threats emerged. Russia's incursions into Georgia in 2008 and the Crimea and Ukraine in 2014 were led by significant numbers of well-equipped ground forces. Their aggression was a clear reminder of the importance of conventional, armored forces, and it spurred European LCS defense investments and discussions of US heavy forces in Poland.[4] At the same time, China's increased military spending and bellicosity in the South China Sea have driven a re-evaluation of US strategy, the "Rebalance to the Pacific" captured in the *National Security Strategy* (NSS).[5] This shift, which focuses on naval and air capabilities

to provide freedom of navigation and deter outright aggression, places demands in direct competition with those coming from Europe. So far, that a tug of war has largely favored air and sea power at the expense of LCS development and procurement. The flat or reduced DoD budget, focus on the Pacific, and increased terrorist threats in the Middle East and Africa do not foretell a large-scale investment in improved Land Combat Systems, despite European concerns.

TWV MARKET: CURRENT CONDITIONS, OUTLOOK AND CHALLENGES

The TWV market is a healthy and highly competitive defense market with its foundation in the high volume commercial truck industry. There are three diverse buyers, US Army, US Marine Corps, and foreign militaries, all with different requirements. This market is differentiated having new sales and regular aftermarket opportunities for the Original Equipment Manufacturers (OEM), DoD Depots, the Defense Logistics Agency (DLA), and/or teaming through Public Private Partnership (P3) arrangements. The work is somewhat episodic with regular aftermarket and commercial opportunities that maintain revenues and profits during defense downturns. After market work and new procurements after the initial contractual periods have higher margins. All components of the TWV market are working under capacity coming off a decade long spike in spending.

The TWV market within the military vehicle or LCS industry is composed primarily of trucks designed specifically to satisfy military requirements for rough terrain mobility, environmental extremes, and survivability. The TWV industry's foundation is the large and diverse US and foreign commercial truck industry. Although military trucks typically have a military unique design, they are largely built using the same parts and components (i.e., engines, tires. transmissions, and wheels) used in the manufacturing of commercial trucks. Military specific requirements include advanced suspensions, armoring kits, suppressive weapon systems, radios, and adaptations for carrying military payloads and palletized systems in varying on and off road terrain. US truck manufacturers currently active in the TWV market are: AM General, Freightliner, Mack Defense, Oshkosh, and Navistar. The major European truck manufacturers currently active in the TWV market are: Iveco Defense Vehicles, Mercedes, Rheinmetall MAN Military Vehicles, and Renault Truck Defense. In addition to the OEMs, DoD Depots, and DLA all compete for aftermarket work to include rebuilding components, vehicle service life extension programs (overhauls, rebuilds and upgrades), and supply chain management for consumable parts used for routine maintenance and repairs.

Current TWV types include light, medium, and heavy trucks that primarily serve in combat support and combat service support roles (See Appendix B, D). Light trucks include the High Mobility Multi-purpose Wheeled Vehicle (HMMWV), Joint Light Tactical Vehicle (JLTV), and US Special Operations Command (USSOCOM) Ground Mobility Vehicle (GMV). Medium trucks include the Family of Medium Tactical Vehicles (FMTV) and Medium Tactical Vehicle Replacement (MTVR). Heavy trucks include the Heavy Expanded Mobility Tactical Trucks (HEMTT), Palletized Loading System (PLS), Logistics Vehicle System Replacement (LVSR), M915/M916 Line haul Tractors, and the Heavy Equipment Transporter (HET). The Combined TWVs inventories for the Army and Marine Corps totals roughly 292K vehicles.

The TWV market has many strengths. There is strong competition in a relatively open market with a commercial foundation. This robust, diversified, and high-volume commercial foundation provides economies of scope that allow TWV suppliers to weather the episodic demands of DoD procurements. The TWV manufacturers have large domestic and foreign parts and service networks that can support DoD and foreign military customers globally. Major components (i.e. engines and transmissions) are supplied by high volume commercial manufacturers that sell high quality products at affordable prices due to market competition and economies of large-scale production. Finally, the volume of US and foreign TWVs in service allow lucrative OEM aftermarket revenues and opportunities to team with Depots through P3 arrangements.

The TWV market has some weaknesses but they are, for the most part, manageable. All segments of the TWV market (manufacturers, suppliers, and depots) have significant excess capacity that results in higher overhead costs. For private sector firms, excess capacity is a result of reduced demand stemming from the economic/procurement downturn after 2008. In the long run, demand will pick up or firms will reduce unneeded capacity. Reducing depot capacity for TWV work, however, is problematic due to the strong constituent politics involved in downsizing the depot system. US export control reforms involving the transfer of some TWV items from the Department of State's *US Munitions List* to the Department of Commerce's *Commerce Control List* has resulted in new challenges. Some firms report the export of military trucks is now more complicated as firms have to learn to work with the different processes of two agencies instead of one. Government intervention creates other inefficiencies for the TWV market. To sustain the depots with labor hours, Congress has mandated OEMs share depot-level repairs and overhaul work equally with them. Yet, firms report they do this work faster, better, and cheaper than the depots. If they are to be believed—and given that depots aren't incentivized to be efficient or to produce quality work via their work guarantee this is credible—then this sharing arrangement might not be a good value for taxpayers. Furthermore, the surge capacity OEMs demonstrated during the spike in production from 2003-2010, undercuts the argument that preserving depot capacity, especially that dedicated to TWV work, is essential.

Another weakness, arguably the most significant in the TWV market, stems from the Army and Marine Corps preference for pure fleets (using a single model of a particular military vehicle). The services have long argued that pure fleets simplify supply chains (less costly to order and stock repair parts for a single make-model as opposed to multiple make-models) and maintenance schemes, thus saving money in the long run. But such arguments drive the services to sustain their TWV fleets through upgrades and rebuys that highly favor (if not specify through sole-source contracts) the incumbent firm and thus create what some term "vendor lock." This dynamic undermines the competitive nature of the market and allows firms to negotiate higher sole source prices and earn higher profit margins than possible under competitive bidding.

Firms competing in the TWV industry face a number of challenges. Competition for some programs drives prices so low that firms occasionally exit the TWV market. The "winner takes all" nature of TWV competitions also forces some firms out of the market when they are unsuccessful in winning a program. This happened to BAE when they lost the FMTV contract to Oshkosh, which had bid a significantly lower price.

Having no other truck contracts, BAE shut down their truck plant in Sealy, Texas and exited the market. The FMTV case, because it was a competitive bid to buy more trucks based on the Technical Data Package the government had bought, points to an emerging challenge within the market. To maintain the benefits of competition in future buys or aftermarket work, the government has an interest in securing the TDP for military vehicles and recently has included affordability of the TDP as a criterion for selection in production contracts. However, some OEMs take exception to this practice and view the provision of their Intellectual Property (IP)—created at substantial costs through Independent Research and Development—as the surrender of future business. By making the TDP part of source selection, the government imposes a prisoner's dilemma on competitors: sell the TDP cheaply and risk follow-on business, or price it too high and miss out on the deal altogether.[6]

Perhaps the greatest challenge to the market is waning US demand. The strategic "Rebalance to Pacific" called for in the *National Security Strategy* places a premium on air and sea power. With strategic priorities thus focused, ground forces will be hard pressed in the competition for DoD resources to obtain funds for TWV programs. Added to that, as the overall Defense budget shrinks as many predict it will, budgeteers will look to reduce ground forces, which many argue are more easily generated in a time of conflict compared to air and sea forces. Reduction in size of the Army combined with reduction in funding for Army and Marine Corps operations threaten continued sales and aftermarket opportunities within the TWV market. As a second order effect to reduced force structure, the availability of free TWVs under DoD's Excess Defense Articles (EDA) program will reduce opportunities for firms trying to sell military vehicles to foreign military customers.

The outlook for the Tactical Wheeled Vehicle Market is quite positive, even in the absence of a major procurement program other than JLTV over the next decade. Firms have demonstrated significant resourcefulness in their ability to leverage technology, commercial components, and production know-how from the non-military segments of their business. They've shown great resilience in their ability to merge civilian and military assembly on the same production lines, achieving efficiencies and sustaining production capacity even through downturns in defense procurement. Though those same OEMs may bristle at the notion of making an affordable TDP part of source selection, this mechanism will help government assure competition in follow-on contracts and avoid the "franchise building" that has plagued the combat vehicle market. Indeed, the strength of the TWV market has been and will continue to be its linkage to the larger commercial market (technology, parts, production facilities, etc.) and the opportunity that affords the government to allow the TWV market to operate freely. With this in mind, the greatest opportunity to improve the market rests in pulling back where the government most forcefully inserts itself: depot maintenance and overhauls. Firms demonstrated their ability to meet demand as the DoD recapitalized large portions of the TWV fleet in the 2000's; this should encourage leaders concerned with maintaining strategic capacity to rethink the need for maintaining a government-owned and government-operated depot capacity for TWVs.

COMBAT VEHICLE MARKET: CONDITIONS, OUTLOOK & CHALLENGES

The US Combat Vehicle (CV) Market is a highly specialized, military-specific segment of the LCS Industry. Combat Vehicle producers use sophisticated armor, sensor, and weapon technologies to design and build vehicles that are markedly different from TWVs. CV firms produce a variety of systems, both wheeled and tracked, including tanks (M1 Abrams), cavalry and infantry fighting vehicles (M2/3 Bradley, LAV), armored personnel carriers (M113, Stryker), amphibious assault vehicles (AAV), self-propelled artillery (M109, MLRS), and other specialized armored vehicles (M9 Armored Combat Earthmover, M88 Armored Recovery Vehicle, Armored Vehicle-Launched Bridge AVLB) (See Appendix E). Historically, tracked vehicles dominated the CV market, largely because only tracked systems could maintain cross-country mobility for armored vehicles weighing more than twenty tons. More recently, automotive technologies have advanced to the point of providing near equivalent mobility for wheeled systems in excess of thirty tons, and as a result wheeled variants, which are generally less expensive, have gained market share domestically and internationally.

Like most of the defense industry, the combat vehicle market has endured dramatic contraction over the past two and a half decades (Appendix F). Before 1990, more than eighteen firms competed in the market as either a prime or major component supplier. Today, only two firms remain as committed producers of American combat vehicles: BAE (an American subsidiary of a firm based in the United Kingdom) and General Dynamics Land Systems (GDLS). Other firms, such as Lockheed and SAIC, have competed for new combat vehicle programs and are beginning to make inroads in the market, but BAE and GDLS have established dominance over the last two decades.

BAE Combat Vehicles, the division of BAE responsible for the US combat vehicle market is based out of York, PA, which also houses its main production facility. There BAE fabricates combat vehicle hulls from ballistic grade steel and aluminum and completes assembly of both new and overhauled hulls. The company participates in a public-private partnership with Red River Army Depot for the recapitalization of Bradley A3 vehicles and other programs. BAE has also periodically partners with Anniston and Letterkenny Army Depots on vehicle programs. BAE's portfolio of CV products includes the M2/3 Bradley family of vehicles, M88, M109A7, M992A3, and AAV. However, over the past two years, the company's combat vehicle business has been kept afloat by congressional additions to the defense budget for minimum sustaining rates of production of the M88A2 and ongoing work on the M109A7 self-propelled howitzer and matching M992A3 ammunition carrier. With the award of the AMPV contract on December 23, 2014, BAE will be able to climb further out of the production/profit "bathtub" it entered after wartime sales declined precipitously after 2012. It improved its position further by winning one of two Engineering and Manufacturing Development (EMD) contracts for the Amphibious Combat Vehicle (ACV 1.1) program, which it won partnering with Italy's Iveco Defense Vehicles, maker of the SuperAV and other combat vehicles.

GDLS, also a business unit of General Dynamics, operates on a significantly different model than its main competitor. Its parent company ranks in the top 100 of the Fortune 500 and posts annual sales of nearly $31 billion.[7] GDLS' largest production facility is the government owned "Joint Systems Manufacturing Center" in Lima, Ohio, where the company is both the contracted manager of the facility and its largest tenant. GDLS also leverages government-owned facilities through a P3 leasing arrangement at

Anniston Army Depot (ANAD) located in Anniston, Alabama. There it completes fabrication of domestically sold Stryker vehicles and participates in a P3 with the depot for the M1A2 SEP V2 recapitalization program. It also maintains, via its subsidiary GDLS Canada, a facility in London, Ontario that fabricates hulls and assembles wheeled combat vehicle products for Canadian, US and foreign markets. Within the American CV market, GDLS produces the M1 tank, Stryker family of vehicles, and LAV, as well as the Cougar, Buffalo, and RG31s (protected vehicles) for route clearance units. Like its competitor, GDLS saw a substantial down turn as America's involvement in the wars Afghanistan and Iraq wound down. *IBIS World* reports that in 2010, as the company was still fielding Strykers, it earned revenues of over $2 billion in domestic sales, while US sales during 2013-2015 have hovered at about $1.3 billion.[8] Today, production lines in Lima generate about one M1 per month and a Stryker every week. And while domestic sales are lagging, the international market is largely taking up the slack.[9] *Hoovers* reports that GDLS' total sales in 2015 were $3.5 billion implying its foreign sales were over $2 billion surpassing domestic sales by over 50 percent.[10]

High barriers to entry to the combat vehicle market combined with the boom-bust demand cycle have kept new entrants at bay for years. To produce vehicles in the combat vehicle market requires a substantial capital investment, both in the facilities and tooling to construct the product and the personnel to design, fabricate, and assemble it. The specific knowledge needed to integrate complex systems like those on modern combat vehicles is extensive, not something a new entrant could pick up easily or cheaply. Unlike the TWV market, the combat vehicle market lacks a commercial analog from which to borrow technology and talent. Perhaps more importantly, though, is that the combat vehicle market rises and falls through infrequent, all-or-nothing opportunities where DoD procures a combat vehicle fleet and then maintains it for 20, 30, even 50 years. The costs of switching from one product to another are simply too high.

But barriers do not preclude new entrants altogether. In the last year, a newcomer to the combat vehicle market has found a foothold. SAIC, a company that had no prior experience in building combat vehicles, bid successfully in the contract to install survivability (and other capabilities) upgrades on 392 of the Marines' aging AAVs.[11] In November, 2015 the Navy awarded SAIC a $121.5 million contract to build prototypes in the EMD phase of the ACV 1.1 program. Touting itself as a technology integration company, SAIC teamed with ST Kinetics to submit the Terrex 2 for the ACV 1.1 competition. How well SAIC performs in its first foray into turning wrenches on combat vehicles is yet to be seen, but their success points to a way that others might gain entry into the combat vehicle market. Partnering with a foreign firm with solid vehicle designs and engineering experience may reduce the knowledge barrier for new entrants, especially those with complimentary expertise, and allow them to break the apparent BAE/GDLS duopoly.

The combat vehicle market has demonstrated a number of strengths in recent years that speak to its resilience and the outlook for the future. First, for new programs, competition remains high despite the apparent dominance of BAE and GDLS. For example, the ACV 1.1 contract, which will only lead to the production of 220 vehicles (16 prototypes and 204 production models), drew five competitive bids, three of which came from newcomers (SAIC-ST Kinetics, Lockheed Martin, Advanced Defence Vehicle Systems (ADVS).[12] What's more, the competitors show a willingness to invest their

scarce Internal Research and Development (IR&D) dollars to set their products apart from others. This investment speaks to a larger strength of the American industry: extensive and sophisticated design and systems engineering capabilities.

The sometimes fraught interaction of the government and private industry in many ways separates the American combat vehicle market from others. First, US investments in Science and Technology (S&T) eclipse its allies and enemies. Second, the government goes to great expense to ensure security of supply by maintaining redundant capabilities to both produce and maintain the combat vehicle fleet. Through a combination of direct funding and workload management, the Department of Defense and Congress (sometimes working at odds) sustain depots at Red River, TX; Anniston, AL; Albany, GA; and Barstow, CA (See Appendix H); as well as the Joint Services Manufacturing Center (JSMC) in Lima, OH. It has also shown a willingness to sustain company owned facilities like those at York, PA by funding minimum sustaining rates of production. Third, the government maintains highly capable testing facilities and capabilities, such as the Aberdeen Testing Center at Aberdeen Proving Ground, which ensures only products of the highest quality enter the DoD inventory. Last, through a comprehensive system of export controls, including scrutiny of potential client-state's abilities to safeguard technology by the Defense Technology Security Agency (DTSA), the government imposes security of information. In so doing it safeguards the qualitative advantages US ground forces enjoy from potential adversaries.

Despite the taxpayers' contributions and the government's best intentions, the US CV market still has substantial weaknesses. First among them is structural, driven by the contraction of the market down to two dominant suppliers. Should one of them choose not to compete, the buyer loses the benefit of competitive pressures. Arguably this has been the case as BAE and GDLS staked out their segments of the market—GDLS with tanks and Strykers, BAE with Armored Recovery Vehicles, Bradleys and howitzers—and protected them. Prohibitive switching costs then imposed a kind of "vendor lock" as the buyer (DoD) became wedded to a company's product. Rebuy and upgrade contracts thus favor the incumbents, now free from market pressures to hold down prices. The government's seeming inability to maintain an accurate and complete TDP for something as complex as a modern combat vehicle exacerbates the problem.

Just as government action strengthens the CV market, in other ways government management creates inefficiencies that weaken it. The greatest of these is the government's investment in capacity, maintained ostensibly to preserve the ability to surge production in a time of war, but which now leads to multiple facilities operating at a fraction of their baseline capacity. Even at the height of wartime production in 2008-2011, combat vehicle facilities in the US – government and for-profit – were not at full capacity (None of the major government or for profit facilities went to 24 hours, seven days a week production schedule.). While the industry has shed workers and revamped compensation programs, it hasn't contracted physically, largely due to Congressional activism. While some surge capacity can be justified from a national security perspective, the costs of maintaining capacity excess to likely surge requirements results in unnecessary higher per unit costs of combat vehicle products.

Government management introduces other inefficiencies that cost taxpayers without always achieving the intended outcomes. One of these is the willingness of the DoD to fund research within its own labs and research centers, but it also plays out

through development contracts for OEMs to take mature technologies and integrate them on new platforms. Theoretically, this arrangement is necessary in order to realize leap ahead or even qualitatively superior equipment, but DoD's track record of integrating new technology into combat vehicles over the past two decades has not been encouraging. In particular, despite spending just under $20 billion dollars on the Future Combat System (FCS), the Army never produced the proposed systems, and all those R&D dollars could not produce the revolutionary capabilities (like armor that could protect a 20-ton combat vehicle) the program promised.[13] [14] Meanwhile, firms in other countries often must go it alone, spending their own profits to develop new systems. Krauss-Maffei Wegmann (KMW) developed the Dingo, one of the first protected tactical wheeled vehicles, with its own money in the 1990s. American firms lack the incentive, and indeed are absolutely skittish about investing heavily in future products. Instead they are incentivized to wait for contracts against very specific requirements or, as has been the case in recent contests, leverage European research by partnering with firms that have developed modern combat vehicles (Puma, Boxer, SuperAV, etc.).

The CV market faces additional challenges that threaten its ability to operate efficiently and ultimately to provide the products the US military needs. First among them, the environment of infrequent combat vehicle buys creates a sparse series of all-or-nothing competitions by which firms live and die. This has long been the case, but as combat vehicles have become more sophisticated and expensive the justification for replacing them has been harder to make; instead, a trend of updating or improving current systems has prevailed. The Army's current Vehicle Modernization Strategy puts this to practice, delaying potential fielding of a new tank as late as 2050 and a replacement for the Bradley Fighting vehicle to the mid 2030's. At the same time, the market has undergone significant contraction since the 1990s, shrinking to two incumbent firms, GDLS and BAE (See Appendix F). While this consolidation has taken place across the larger defense industry, the result within the combat vehicle market is that firms have staked out territory and defended that turf over the course of decades. And while other firms have shown up to compete for new combat vehicle programs, in the end these two have taken command of the US combat vehicle fleet and positioned themselves for follow-on contracts. Indeed, by maintaining control over the Technical Data Package, these firms have essentially established franchise businesses. The government, apparently unable to keep up with modifications and technical specifications for these complex platforms, has become reliant on the original manufacturer for rebuys and upgrades and thus imbued them with immense market power that drives prices higher.

This dynamic has allowed BAE and GDLS to survive within the US CV market and navigate through times of boom and bust, largely based off of US sales alone. However, they, like firms in the TWV market, are realizing they need foreign sales to remain profitable. Though aided by the fact that their products are used by the most powerful military in the world (a unique selling point), US combat vehicle firms must overcome significant hurdles to succeed in foreign markets. First, their products are sophisticated and expensive and thus pose a challenge to even well-to-do countries to buy and sustain them. The rising dollar has only made matters worse, but government regulation restricts sales even when a competent buyer is available and uniformly draws out even small-scale transactions over the course of years. The International Traffic in Arms Regulation and the litany of review processes that support it impose strict

limitations on export of military end items and the individual components that make up an end item. And, while other countries have similar mechanisms, the US ITAR is widely considered the most restrictive and the most byzantine.

The outlook for the future of the combat vehicle market is mixed. On the one hand, there are no quick solutions for the structural inefficiencies of the market readily at hand. Adjustments that are needed within the overall combat vehicle industrial base will require Congressional action against the grain of constituent interests in some cases, and this will not come easy. Nor is it likely that the paradigm of infrequent buys will change or that defense spending will suddenly pick up in the foreseeable future. However, some optimism is warranted. First, it seems that the difficulties of the last two decades and post-war reflection are driving clear-headed thought. As a result, the Army has articulated a long-term vehicle modernization strategy, one that sets realistic goals and establishes priorities for procurements. Recent years have also provided positive models of acquisition both in the TWV and CV markets, models that leveraged mature technology and addressed stable, clear requirements. Lastly, the entry of new players into the combat vehicle market (SAIC, Lockheed Martin, and foreign firms working with domestic partners) offer new, perhaps better, models for structuring industry that may allow us to shed some of the inefficiencies of the past.

GOVERNMENT GOALS AND ROLES

The government plays a significant role in the LCS industry as a buyer, regulator, and financier. Because it performs all of these roles, the government has a great deal of power over the industry. As previously described, the tactical wheeled vehicle market is largely based upon commercial products and leverages a very large and vibrant commercial truck market. In contrast, the combat vehicle market is composed of military unique items with little commercial cross over. As a result, the government has more power, and more responsibility to shape the combat vehicle portion of the industry.

The government is limited in the execution of power because it is diffused across different agencies and branches of government that often pursue divergent interests. The US government, as a sovereign, has the power to set the terms of competition and rules for sole source procurement to include the determination of fair and reasonable prices and profits. The State Department oversees international sales of items on the U.S. Munitions List (USML) through the International Trade in Arms Regulation (ITAR) process. The Department of the Commerce oversees the sale of items on the Commerce Control List (CCL). The Department of the Treasury oversees the Committee on Foreign Investment in the United States (CFIUS) process to control ownership of critical U.S. industrial capabilities and knowledge. Each of these agencies has its own perspective and interests that aren't always congruent with one another. As such, they are frequently insensitive of their impact on the LCS industrial base.

DoD, as a whole, has certain goals for the LCS Industry to support national security interests. The government desires the capability to produce the most technologically advanced weapons in the world in order to sustain a competitive advantage on the battlefield. The government desires adequate military vehicle production surge capacity to meet wartime requirements. The government prefers American control of critical capabilities in the LCS industry to ensure security of supply

and security of information. Finally, the government seeks to achieve these goals at the lowest possible cost to the taxpayer.

In practice, achieving these goals in an economic manner is a difficult challenge for the combat vehicle portion of the LCS industry. The limited commercial application for advanced combat vehicles means there is little incentive for firms to invest the significant capital required for development and production. The result is heavy government intervention into the market through both government injection of capital to support development and production capacity and restraining regulation under the International Traffic in Arms Regulation (ITAR).

For the production phase of programs, the government will frequently provide substantial capital to support manufacturing and assembly of systems and major components, i.e. facilities and tooling. The level of capital support varies from minimal support to BAE at the York production facility to the extensive support to the Government Owned, Contractor Operated (GOCO) Joint Services Manufacturing Center in Lima, Ohio. The results of an Army sponsored analysis of the industrial base indicated there was an abundance of large scale machining capacity that represented an opportunity for consolidation[15]. Given the documented excess capacity in some areas and the variety of management structures and sharing of capital costs present in the industry, it isn't clear if government ownership is actually necessary to ensure adequate production capacity.

The US, in practice, requires domestic/North American production of LCS end items and major components to ensure security of supply and information. North American production eliminates the risk of U.S. military readiness being reliant upon the continued friendly relations with other sovereign nations. Similarly, domestically owned intellectual property in the design of the system and major components places the systems under the U.S. Munitions List subject to ITAR restrictions in export. This serves the national interest by denying other countries state-of-the-art technology for a period of time, extending the time period U.S. forces maintain a technological advantage. This reduces the frequency that the United States must advance technology, but harms domestic firms by restricting their opportunity for worldwide sales.

The U.S. attempts to balance these goals while minimizing the cost and remaining committed to private ownership. In contrast to some European countries, the U.S. generally avoids ownership of firms except under extreme circumstances, and then only for as long as necessary for the firm to stabilize and survive. Given the government's goals, the structure of the market and the interplay between industry, their elected representatives, and military establishment, the U.S. does an acceptable job in keeping everyone equally unhappy.

MAINTAINING THE COMBAT VEHICLE INDUSTRIAL BASE

In the post-Cold War years, significant efforts have been undertaken to ensure the nation's ability to rapidly produce technologically superior arms when needed, with sufficient capacity to wage war and achieve political objectives. In the current environment of fiscal uncertainty the central issue of *what must be maintained* lingers. The Combat Vehicle Industrial Base (CVIB) is comprised of both for-profit and organic sectors, each with a unique set of requirements. The for-profit sector of the CVIB is made up of two firms, both reliant on government owned capital stock, to include not just product specific tooling, but in the case of GDLS an entire factory (Joint Systems

Manufacturing Center, Lima, OH). These firms act as horizontal integrators of technology, largely serving as assemblers of component systems and subsystems manufactured elsewhere. The second and third tiers of the supply chain consist of those firms manufacturing the essential components of the final system. As many of these components are unique to combat vehicles, the government must bear the expense of keeping production lines open despite low requirements in order to ensure security of supply.

The organic sector of the CVIB reinforces the for-profit sector. Consisting of the Anniston Army Depot, Red River Army Depot, Albany and Barstow Marine Corps Depots, and the aforementioned Joint Systems Manufacturing Center, the organic CVIB provides a highly responsive, though somewhat inefficient, alternative to total reliance on for-profit entities. Aside from incentivizing efficiency on the part of commercial firms, the organic CVIB is mandated to "ensure a ready and controlled source of technical competence and resources necessary to ensure effective and timely response to a mobilization, national defense contingency situations, and other emergency requirements."[16] Though a minimum of 50% of annual depot-level maintenance funding is required by Title 10 to be performed within the organic industrial base, there currently exists considerable excess capacity at the five organic locations, largely due to reductions in system upgrades, RESET / RECAP, and Foreign Military Sales orders.

The capability to produce armaments consists of more than just factories. Indeed, the CVIB is comprised of a variety of activities, some more critical than others. Recent analysis of industry fragilities has pointed to specific areas where the government should focus its efforts to sustain the industry. A recent AT Kearney study commissioned by US Army PEO Ground Combat Systems identified critical skills such as ballistic welding and design engineering, as well as potential supply fragility for FLIR systems and track and transmissions for tracked combat vehicles. Historically, the CVIB has been maintained through the continual procurement, refurbishment, and upgrade of combat vehicles. As asserted in the AT Kearney report, conducted in cooperation with the combat vehicle supply chain and validated by GAO, ensuring security of supply for CVs can be accomplished at a far lower cost to the taxpayer through targeted procurement of critical systems, retention of critical skills at depots and industry, and a cost-benefit based consolidation of the Organic Industrial Base (OIB).

There are considerable barriers to such a dramatic shift in industrial base policy. The current geographic positioning of combat vehicle OIB facilities create considerable incentives for congressional intervention on behalf of their constituencies, and a consolidation of facilities will likely face intense dissent. It is thus necessary to expand the realm of the possible, and consider new paradigms for use of government owned facilities. One potential model to follow is NASA's Michaud Assembly Facility, which currently hosts tenants such as Boeing, British Petroleum, and the Coast Guard in a variety of governmental and commercial entities. Overcapacity in the CVIB can be reduced through the conversion of capital from military specific uses to commercial efforts, thus retaining surge capacity without having to continually procure small batches of complete systems in order to maintain manufacturing capability.

LCS SUSTAINMENT STRATEGY

Security of supply in the Land Combat Systems (LCS) market consists of not just the ability to produce new systems, but the entire supply chain. This supply chain is spread across OEMs, the Defense Logistics Agency (DLA), and the DOD supply chain infrastructure, which includes Army Material Command and Marine Corps Logistics Command, parent commands of the LCS depots and arsenals. The supply chain consists of parts procurement, quality management, inventory level management. The DLA mission is to supply consumable parts and newly procured Depot Level Repairable[17] (DLR) items, which may be complex, and therefore expensive. Due to the expense of new procurement, these parts are typically rebuilt or overhauled instead of being replaced. As a result of a 2005 BRAC decision, DLA is responsible for buying "new" spare DLR items to replace unserviceable parts. Essentially, DLA has a role in supply chain management, but a limited one. It only handles consumables under the assumption that they should be bought in large numbers, and purchasers could benefit from scale.

DOD depots are required to use DLA when ordering consumable parts, which may be problematic. DLA is not required to procure parts from an original equipment manufacturer (OEM). Instead, when DLA contracts for production and procurement, it uses technical production data and specifications to define the part, which can lead to a number of complications that can result in the procurement of parts that do not conform to technical requirements. Because DLA procurement personnel lack engineering expertise and must rely on the customer to verify parts acceptability, parts may be unreliable, might not fit, or otherwise not meet standards. DOD activities are able to waive policy requirements to use DLA by purchasing kits, which are defined as a specified set of parts that can be used to overhaul or rebuild a component. Therefore, to reduce the likelihood of non-conforming parts, depots and PMOs sometimes contract with OEMs for kits to fit specific replacement or reset needs on a combat vehicle. This "end-around," although effective, is only used to ensure quality and fit. While this solution meets the short-term needs of the PMO or depot, it does not solve the root cause of the problem: DLA's inability to obtain technically conforming parts on a consistent basis.

DLA parts may also be more expensive than OEM parts. Although the DLA efficiency cost recovery rate (CRR) supply chain composite rate for all commodities is less than 14%, the rate is nearly 30% for consumable parts used with weapon systems, including TWVs and combat vehicles. The CRR for a DLA might be partially reflected in the agencies excess parts overhead or required stock repurchasing. A 2010 GAO report stated that, "the agency had significantly more spare parts secondary inventory than was needed to meet current requirements...of this total, about $7.1 billion (52 percent) was beyond the amount needed to meet the requirements objective."[18] These inventory levels drove DLA to dispose of "about $1.9 billion … in economic retention stocks" to meet inventory goals, but it will likely have to repurchase much of what it sold.[19] This difficulty is exacerbated by inaccurate demand and lead-time forecasting as the purchase of low demand parts reduces funding available for more critical parts.

There is a need for a renewed DOD management focus on inventory control, managing stock levels and backorders. DLA should leverage current OEM predictive capabilities for wear rates and order forecasting. A current public-private partnership (P3) effort between Caterpillar (CAT) and Red River Army Depot, created for overhauling

CAT engines, uses stored electronic engine metadata, which forecasts requirements through statistical failure levels, reducing order lead times and back orders and minimizing unscheduled downtime and failures. Additionally, as CAT is serving as supply chain manager for these engines, the government receives genuine CAT parts at a negotiated discount, which equates to lower operating costs and savings against the DLA supply chain rate.

Streamlining the supply chain management process is a key requirement of overall DOD acquisition management reform. Initial changes include exploring increased use of P3 partnership agreements to provide OEM expertise and metadata. Within the LCS industry, much of the consumable and repairable supply is available commercially, and many OEMs already have efficient supply chain management structures in place. In these situations, it might make more sense for DLA to contract with OEMs to supply parts directly to depots and supply support activities rather than create a competing supply chain management structure. Given their expertise with the equipment they manufacture, OEMs are more likely to procure parts that conform to technical requirements. Similarly, OEMs should be able to obtain lower prices via purchasing economies created by combining OEM and DLA demands.

LCS LABOR & CRITICAL SKILL

Firms in the LCS industry employ workers that are mostly unionized, typically under either the United Auto Workers or American Steel Workers.[20] Overall, there appears to be a positive, non-confrontational relationship between firms and their labor unions.[21] This relationship has been critical as firms have adjusted after the spike in procurement in 2008-2011 that brought with it a peak in labor employed at these firms. One firm reported they currently employed about a third of the workforce present in 2008. As management positioned their organizations for those reductions and future austerity, the unions accepted workforce cuts and negotiations that reduced compensation packages for their members, perhaps in part because OEMs shared their financial health with union leaders and teamed with them to secure the financial health of the organization.[22]

Despite these healthy relationships, some challenges still exist within labor. The majority of the LCS industry workforce is unionized with collective bargaining rights that affect the employer's ability to reconfigure its workforce or change working conditions. In both GOCO and Contractor-Owned, Contractor-Operated (COCO) facilities, employers have reorganized, and replaced some permanent positions with temporary employees who receive little to no benefits. The use of temporary employees, while less advantageous for workers, allows LCS employers to adjust for surges or down turns in the industry and have become more commonplace in response to the new economic environment.[23] Union rules that favor seniority in lay-off/ re-hire decisions are driving the average age of the workforce upwards. Reductions are most often borne by the newer employees. This creates a skewed experience distribution, one resembling a bathtub, concentrated among oldest and youngest employees, which makes it difficult for firms to maintain depth and critical expertise within their labor force.[24] Firms in the United States have an average aged workforce of 48,[25] compared to a younger European workforce with an average age of around 40.[26]

The combat vehicle and TWV market workforce is comprised of three distinct labor groups. The first is the engineering workforce[27], necessary for front-end production design and vehicle integration. This group is highly educated and displays the lowest employment transfer costs. These engineers are also highly sought after by competing industries (both in defense and non-defense industries), presenting a risk to firm's investment in their employees' industry-specific knowledge. This investment could be lost should these individuals depart the military vehicle market and move to other industries (e.g., the automotive industry), which several firms reported as occurring quite frequently in both directions as business cycles ebb and flow.[28] Some firms have actually located their engineering departments near an automotive engineering hub to take advantage of this dynamic.[29]

The second group consists of the production line workers with specialized skills unique to the LCS industry. The most unique of these skills is ballistic armor welding, which is vastly different from commercial welding.[30] The experience required and the extensive qualification process to gain baseline skills makes it very difficult for military vehicle manufacturers and depots to replace these workers; therefore, keeping a minimum number of them employed with a consistent flow of work is critical.[31] Firms have taken steps to partner with local welding schools through internship programs or developed their own training programs.[32] While acknowledging the criticality of this skill, depots do not seem as concerned about this skill set, perhaps because of lower turnover in their workforce.[33]

The last group consists of the remainder of the workforce, production and support labor. These lower skilled workers historically unionized but less so recently, pose the lowest replacement risk to LCS employers. OEMs reported that these workers tend to remain in the local area when laid off during downturns, awaiting the opportunity to return to the LCS industry (where wages are typically higher) in a cyclical movement that has become a typical occurrence.[34] Some firms have begun to further stratify their workforce, removing non-skilled labor from the unions (cleanup crews, for example).[35]

EU CV MARKET

Analysis of the respective combat vehicle markets of the European Union (EU) and the United States yields multiple inherent underlying factors by which these markets can be differentiated, providing greater insight into the US combat vehicle market. As evidenced in Appendix I, (which includes both active vehicles and vehicles in storage) the United States far outstrips European Nations in sheer numbers of combat vehicles. Despite this discrepancy, the United States relies on only two firms, GDLS and BAE for the vast majority of its combat vehicle production; whereas nearly a dozen firms produce combat vehicles in the European market (See Appendix J).

The reasons for this differentiation are numerous, but perhaps most important is the underlying market structure. The US market for combat vehicles is (during the source selection phase of the acquisition life cycle) in essence a monopsony, in which a single consumer determines demand and multiple suppliers compete for a life-cycle monopoly. In contrast, the European combat vehicle market contains multiple buyers and sellers at any given time, resulting in a market structure more akin to monopolistic competition. Multiple producers sell products that are differentiated from each other

(non-perfect substitutes) and competition between firms is based on both product characteristics and price.

Nationalization of industry creates another critical difference between markets, allowing for the existence of a higher number of suppliers for a smaller market. The presence of wholly government owned firms such as France's Nexter, partial government ownership as in the case of Finland's Patria, Italy's Finmeccanica, and Norway's Kongsberg, along with government "golden shares" like the United Kingdom's BAE, creates a bias on the part of acquiring nations to procure from their national brand, despite potential cost savings or capability increases available elsewhere.

Even those firms lacking any direct government ownership tend to benefit from national champion status. Though the European market as a whole is competitive, within a particular nation's borders, there tends to be a single producer for each type of combat vehicle, creating a market in which national orders keep a firm in existence while intense competition in the export market incentivizes efficiency and innovation while driving profit. Increases in combat vehicle procurement from those EU nations without a domestic industrial base as well as developing countries in Asia, the Middle East, and Africa have drastically increased the size of the export market. When coupled with national champion status, European combat vehicle manufacturers are able to remain profitable despite fewer overall sales when compared to the US market.

Within the European Union, individual government regulation of combat vehicle exports has caused considerable turbulence for combat vehicle firms. While generally far less restrictive than the US International Traffic in Arms Regulation (ITAR), some European nations, such as Germany, are at a competitive disadvantage due to more government intervention into foreign sales of military materiel. The ongoing merger of Germany's KMW and the France's Nexter will likely attempt to circumvent these government-imposed constraints, allowing for German combat vehicle capability to be incorporated into a French product, which is more exportable worldwide. A bilateral agreement, the Schmidt-Debre' Agreement of 1972, allows for joint government ventures to export using the less restrictive nation's export laws, but it is unclear whether this permission will apply to private companies, one of several factors leading to the tentative nature of the merger.

Another key difference between the two markets is the increasing trend in the European combat vehicle market toward vertical integration. In the United States, major defense contractors are increasingly postured as system integrators. Original Equipment Manufacturers (OEMs) produce the final vehicle, but most components and sub-components are manufactured elsewhere. European CV firms are bucking this trend in order to take advantage of the higher profit margins enjoyed by second and third tier suppliers. By vertically integrating EU firms may either absorb the profits or use the savings to reduce prices of their end product, thus increasing competitiveness. Additionally, with generally low production numbers, cost savings though competition amongst lower tier suppliers will be negated as fewer competitors are willing to invest in the capital necessary to begin production, resulting in single source vendors with market power. The largely convertible capital of European OEMs has provided them with the ability to produce in house at an overall savings. Even KMW, a larger firm which tends to follow an American-style system integrator model, has made moves toward vertical integration with the recent purchases of Battle Tank Dismantling GmbH, a combat

vehicle disposal firm, and Diehl Defence Land Systems, a producer of suspension systems and tracks for combat vehicles.

Aside from the significant structural differences between the two markets, the mission of combat vehicles in the different markets also plays a role in differentiating the markets. The United States has, since the end of World War II, embraced the necessity of maintaining an expeditionary fighting force.[36] The nations of Europe, though at times committing expeditionary forces abroad, are primarily concerned with defensive operations. This difference permits much more specialization to the European climate and terrain whereas US combat vehicles are required to operate in more diverse environments. The convergence of so many requirements adds to cost and schedule while risking performance. Without the need for a totally expeditionary force, EU nations can invest in less expensive wheeled combat vehicles which are likely to remain on the continent where the ability to operate off-road is less important than maneuvering in urban terrain.

In recent years, the European defense market has seen a gradual shift from tracked to wheeled combat vehicles. Advances in suspension and the ability to leverage commercial powertrains have brought about the ability for wheeled vehicles to approach parity with tracked vehicles while decreasing the logistics tail. This change is visible across Europe, from the Iveco-Oto Melara produced 8x8 Centauro 2 tank destroyer, to the Nexter Scorpion system, consisting of 2,300 4x4 and 6x6 vehicles working in collaboration with 200 upgraded LeClerc Main Battle Tanks. Advances in convertible band track technology in both the United States and Scandinavia point to a future in which the debate over tracks versus wheels fades and requirements generators focus "on system 'capabilities' rather than characteristics, a distinction that seems to be shelving much of the past debate in favour of a greater focus on performance and the development of new technology."[37]

The system development cycle also marks a key difference between the US and European combat vehicle market. While the United States tends to fund the development of military systems through both S&T and R&D funding, as well as Technology Maturation/Risk Reduction and EMD cost-based contracts, EU countries place this burden on the firms themselves. Whereas capital investment in the US combat vehicle market tends toward being DoD funded, resulting in a large portion of capital infrastructure being dedicated to military unique production (even owned by the US Government) European firms are responsible for their own capital investment. This transfer of responsibility incentivizes investment in capital that is convertible to multiple systems or non-military production, which allows European firms to more easily start and stop production and European nations to avoid the necessity of paying to maintain specific capacity during lulls in production, which can extend for years.

US CV S&T/ PROTOTYPING EFFORTS

A consortium of government agencies, private defense firms, non-defense firms, and US allies form the Science and Technology (S&T) enterprise for combat vehicles and tactical wheeled vehicles. Some of these organizations are the Defense Advanced Research Projects Agency (DARPA), Army Material Command elements (TARDEC, ARDEC, ARL), OEMs, and the United Kingdom, Canada, Germany, and Israel. Their S&T initiatives and prototyping efforts enable evolutionary and leap-ahead advancements

for combat vehicles and tactical wheeled vehicles. The thrusts for combat vehicle S&T are captured in documents such as the US Army Combat Vehicle Modernization Strategy (CVMS), the Tank-Automotive Research, Development and Engineering Center (TARDEC) 30-Year Strategy, and the USMC Ground Combat and Tactical Vehicle Strategy.[38]

The three main focus areas for Basic and Applied Research are lighter armor, survivability/protection and autonomous/robotic systems, with S&T also conducted in the areas of mobility, lethality, reducing Soldier cognitive burden, increasing operational energy, and vehicle electronics architectures.[39] Advanced Technology Demonstrations (ATD) and Operational Support (OS) S&T efforts focus more on reducing lifecycle costs and reducing logistics burden than on leap-ahead technologies.[40] Deputy Assistant Secretary of the Army for Research and Technology (DASA R&T) has stated a desire to reduce armor weight by 40%, although it may not be achievable. Even if it were, reducing armor weight might not equate to a lighter CV, but could allow increased weight margins for other requirements such as greater under-armor volume, additional fuel or ammunition, increased fuel efficiency, or increased survivability or lethality. Another important S&T focus area is on survivability and protection; this encompasses enhanced passive armors, adaptive armor, underbelly protection, and Modular Active Protection Systems (MAPS).

The Research and Development (R&D) portfolio for ground combat vehicles received approximately $320M in 2014 S&T funding. Overall S&T funding decreased slightly in 2014 and 2015 from 2013, but has stabilized in 2016 with projected small increases over the Future Years Defense Program (FYDP) (See Appendix K). Through 2025, there is a relatively flat funding profile for combat vehicle S&T. However, funding for combat vehicle S&T is scattered over multiple organizations, potentially diluting its effectiveness.

Responsible agencies indicate that the majority of government S&T is focused on incremental improvements of existing technologies over resourcing basic research for leap-ahead technologies. OEM Independent Research and Development (IRD) correctly look at the short-term in order to produce a Return on Investment (ROI), but there appears to be a lack of synergy between OEMs and government R&D organizations. While the OEMs felt industry was better suited to have the lead for prototyping, one government organization argued the importance of getting federal researchers involved in prototyping.

Although there are challenges with combat vehicle S&T, there are several upsides. Even in these austere times, there remains sufficient funding for basic research, applied research, and advanced technology demonstrations to maintain a knowledgeable pool of scientists and engineers. This helps maintain the US intellectual capital required for combat vehicle development. Our laboratories, design facilities, prototyping capabilities, manufacturing technologies and test facilities remain world-class and are capable of supporting surge requirements. Finally, the requirements communities have made great strides in capturing current and future requirements and operational concepts, which help focus combat vehicle S&T efforts in the near-to-mid terms (2016-2031).

New Start Combat Vehicle versus Upgrades

The United States Army and Marine Corps face tough decisions on determining whether or not to upgrade an existing combat vehicle or pursue a new capability. In today's fiscally constrained environment perhaps the greatest justification for a new program is one based on cost, where the price tag for a new system rates better than that of maintaining an older one. But the design flexibility of the M1 series tank and Bradley series fighting vehicles has made the decision to develop newer systems hard to make. The Army has tried twice to replace the Bradley, first with Future Combat Systems (FCS) and then with the Ground Combat Vehicle (GCV). Both programs failed due to marginal capability gains over an upgraded Bradley compared to the associated costs. The estimated cost of GCV was $28.8B dollars compared to $19.5B for the Upgraded Bradley.[41] Similarly the quality and flexibility of the design of the M1 series tank has allowed multiple upgrades, delaying replacement plans till at least 2050.[42]

New programs are the result of a value-based decision; cost versus capability obtained. The Army and Marine Corps recently achieved successful Milestone B decisions on the Armored Mobility Protected Vehicle (AMPV) and the Amphibious Combat Vehicle (ACV) 1.1 respectively. Both programs were justified by length of service, Diminishing Manufacturing Sources Material Shortage (DMSMS), and growing operating costs to maintain existing platforms. Ultimately, there comes a point where the costs to maintain the current system approach the cost to replace it. The AMPV at a Program Costs of $10.2B dollars provides the Army with a cost effective replacement for the M113 initially fielded in 1960.[43] The ACV 1.1 has a target total cost of $ 2.77B compared to the AAV at $2.89B.[44]

The formula for keeping costs contained and achieving program success starts with defining achievable requirements and sound program execution. Requirements must be based on technical reality and the cost to obtain them. Each service must know what it wants and adhere to the plan, because changing requirements during development is costly and jeopardizes a program. The requirements and the plan must be clearly communicated to all stakeholders, especially industry. (See Appendix L for an example of how the USMC articulated the ACV plan.) The ACV 1.1 Program Office hosted three Industry Days and produced three complete Draft Requests for Proposals (RFP), followed by a one on one meeting with each vendor prior to the official RFP release. This continuous communication promoted transparency and a common understanding of achievable and affordable requirements, significantly increasing the probability of program success.

For future programs, the Army and the Marine Corps must define exactly what capability they need, determine if it is technically realistic, and most importantly, fiscally realistic. This must be coupled with both services developing a common perspective on Science and Technology (S&T) investments that lead to real capability advantage, that when weighed against the upgrade calculus, clearly points to a new system. The future of Future Fighting Vehicle (FFV) and ACV 1.3/2.0 will depend on it.[45]

US WORLD WIDE SALES

Foreign Military Sales (FMS), Direct Commercial Sales (DCS), and transfers of Excess Defense Articles (EDA) to foreign vendors have been a noteworthy and increasingly critical aspect for the maintenance of this particular portion of the US Defense Industrial Base (DIB). The benefits of these international sales/transfers will

become more instrumental for our DIB as future budget outlays shrink. US policies should both encourage and enable sales to allied and partner nations as the nation receives a direct benefit at a time when combat vehicle vendors have consolidated to less than a handful. Furthermore, the government has a vested interest in maintaining "warm" production lines for future contingencies.

Domestic Minimum Sustainment Rates (MSRs) will be difficult to achieve at commercial manufacturing centers without foreign sales, and the industry is obligated to its shareholders to find and capitalize on new markets. BAE's international revenue is expected to account for 30% of its revenue in the next five years.[46] General Dynamics Land Systems' international sales already account for more than half its revenue.[47] Whether production is at a GOCO or COCO facility, per unit costs drop when there is higher volume so it behooves the government to support international sales whether FMS or DCS. The US TWV market was strengthened when Afghanistan purchased 2,300 Medium Tactical Vehicles (MTVs) in 2015.[48]

In addition to exports maintaining a warm industrial base and the associated positive cost impacts, there are other tangible benefits. There is a substantial logistics footprint for combat vehicles. Increased commonality of equipment amongst allies and partner nations increases interoperability and could allow for a consolidated supply chain in the event of even modest military operations. Increased commonality amongst tires, tracks, engines, and transmissions between allied main battle tanks, tracked and even wheeled vehicles offers the opportunity for decreased logistics costs since these are generally the spare parts items of largest cube and often weight (aside from the actual tracked vehicles).[49]

The International Traffic in Arms Regulations (ITAR) requires licenses for U.S. defense articles to be exported. Industry provided mixed reviews of this process despite recent shifts of burden from the U.S. Department of State to Commerce. GDLS leverages its manufacturing operation in Canada, where the export approval process is timelier and less burdensome. The refurbishment and upgrading of 150 M1A1 Abrams main battle tanks for Morocco will aid in maintaining the low production rates at the GOCO plant in Lima, OH and Anniston Army Depot in Anniston, AL. BAE, in contrast, is manufacturing in the U.S. and not producing variants of a Bradley, M109, or M-88 for export at the current time. To aid in maintaining the combat vehicle industrial base in a warm status, the US could revamp ITAR rules for exporting legacy equipment to certain allied and partner nations. Additionally, the process could be streamlined so that these requests are not subject to bureaucratic delays. Otherwise, nations can and will seek products from more export-friendly nations or seek to development their own combat vehicle industrial base.

CONCLUSIONS

Analysis of the United States Land Combat Systems industry, conducted primarily through research of primary sources, yields a handful of overarching conclusions. First, the Tactical Wheel Vehicle market is performing well, providing high-quality products at competitive prices, and it does so because it can leverage parts and components, technologies, and even production facilities from the commercial market. However, the current progression toward greater survivability features for TWVs might result in increased use of military unique technologies and less use of

commercial technologies and facilities. In contrast, the Combat Vehicle market is highly concentrated and given to the development of franchise businesses of particular make-models. Because of the military specific nature of CV products, firms rely on US government sales, which are few and far between. As a result, the CV market requires government intervention to maintain critical capabilities, though dwindling budgets necessitate the government look for more efficient ways to do this. Related to that, the industrial base supporting the LCS industry is over capacity, and while commercially owned portions of the DIB have contracted and may shrink further, the organic (government owned component) portion retains excess capacity even beyond recent war time demand. At the same time, segments of the DIB, specifically some first and second tier suppliers to OEMs and ballistic welder capacity, are fragile and require nuanced management. Because of declining domestic demand on the LCS industry, firms are increasingly reliant on exports, though US export controls make this a somewhat difficult proposition. Last, though there has been much hand wringing over the long spate of cancelled LCS programs, recent progress with the ACV, AMPV, and JLTV point out that military vehicle programs succeed when they focus on stable, technologically-achievable requirements.

RECOMMENDATIONS

Based on a broad assessment of the LCS Industry, the following steps to capitalize on the industry's strengths and mitigate its weaknesses should be taken.

Tactical wheeled vehicle depot work should not be considered "core" as it pertains to Title X US Code § 2464 and thus fall outside the legal requirement to retain a government-owned, government-operated core capability to maintain and repair weapon systems to meet wartime requirements. Abundant capacity to overhaul or recapitalize TWVs exists in the commercial market. The close commonality between commercial vehicles and TWVs would allow numerous vendors to perform overhauls and recapitalization work.

The history of failed new combat vehicle programs over the past decade is a result of the pursuit of aggressive requirements requiring immature technology on a predictable schedule, but bending the laws of physics does not frequently occur on schedule. The resulting program slips and cost over-runs made the programs vulnerable to critics, and threatening to other service requirements. Future programs should be built on solidly demonstrated technological capabilities and requirements that are stable, as recent success with ACV 1.1 and JLTV have demonstrated.

In order to improve outcomes from S&T efforts the following steps might be taken. First, increase 6.2 and 6.3 S&T funding to enable near-to-mid-term evolutionary combat vehicle enhancements, and also increase 6.1 funding to develop true leap-ahead technologies that lead to overmatching capabilities. Second, maximize S&T funding effectiveness by developing an overarching governance structure for all combat vehicle S&T funding, perhaps under the auspices of a Board of Governors consisting of principal stakeholders but chaired by one organization (e.g. the Program Executive Office Ground Combat Systems). Additionally, there should be increased partnering of government labs with the OEMs for design and prototyping of new technologies. Last, the government should sustain design engineering capabilities in multiple organizations to foster innovation and competition.

The Army and Marine Corps should revisit the assumption that it is better to maintain pure fleets for TWVs and combat vehicles. Greater automation has aided the parts ordering and stockage systems within the services. At the same time, automotive technologies have advanced to the degree that vehicles are becoming increasingly reliable. By allowing mixed fleets, DoD could take advantage of new technology as it becomes available (through more frequent procurements) and counter the vehicle franchise building that has led to sole source contracts for follow-on buys and upgrades that has been so costly in current vehicle programs.

There is a need for a renewed DOD management focus on inventory control, managing stockage levels and backorders. Toward that objective, DLA should leverage OEM combat vehicle/TWV metadata for wear rates and order forecasting, such as Caterpillar's DICARE (Diesel Engine Diagnostic and Predictive Maintenance) system. DLA should also explore the use of P3 (public private partnership) agreements to provide OEM parts and supply chain management for depot level repairables and the supply support activities supporting operational forces. This will give DLA the support of the OEM for both supply chain and quality control.

Government provided facilities that support the LCS industry, especially the depots, are anachronistically maintained at Cold War era capacity levels. Even at the height of production in 2008-2011 the industrial base was not operating at full capacity. The US government should seriously consider steps to achieve efficiencies and scale our organic DIB to current models of force structure and mobilization. Congress should support DoD recommendations to merge capabilities of depots through BRAC. The DoD should explore new business models for the JSMC facility at Lima, OH to recoup costs associated with maintaining these facilities.

DoD and the Departments of State and Commerce should cooperatively review export controls to streamline the process where possible in order to improve competitiveness of US firms. Simultaneously, US firms should also study the feasibility of developing export models of their products to eliminate or reduce the ITAR hurdles they would have to cross to engage in overseas business. Government representatives at US embassies abroad should support US firms' efforts to secure export contracts.

Notes

[1] Anonymous, (not for attribution discussions with Industry Executive), Spring 2016.
[2] Doug Alexander, "Global Economy's Grinding Recovery Now Norm, Hooley Says,"*Bloomberg*, July 8, 2015, http://www.bloomberg.com/news/articles/2015-07-08/global-economy-faces-grinding-recovery-as-new-norm-hooley-says.
[3] Clifford Krauss "Oil Prices Explained: Signs of a Modest Revival," *New York Times*, May 16, 2016, http://www.nytimes.com/interactive/2016/business/energy-environment/oil-prices.html.
[4] Anonymous, (not for attribution discussions with DoD Executive), Spring 2016.
[5] Cheryl Pellerin, "Asia-Pacific Shift Creates Opportunities, Security Needs," *Defense News*, April 15, 2015, http://www.defense.gov/News-Article-View/Article/604466/asia-pacific-shift-creates-opportunities-security-needs.
[6] Anonymous, (not for attribution discussions with DoD Executive), Spring 2016.
[7] General Dynamics 2015 Annual Report, page 21.
[8] IBIS World Industry Report 33699b, Tank & Armored Vehicle Manufacturing in the US, December 2015
[9] For example, General Dynamics 2015 Annual Report (page 4) notes that GDLS won a $10 billion contract to provide wheeled armored vehicles along with associated logistics support to a Middle Eastern customer through 2028.
[10] http://www.hoovers.com/company-information/cs/revenue-financial.general_dynamics_land_systems_inc.a59593df739abad4.html
[11] United States Marine Corps, *USMC Ground Combat and Tactical Vehicle Strategy*, 29 September 2014, 14.
[12] Ibid.
[13] Sydney Freedberg Jr., "Total Cost to Close Out Cancelled Army FCS Could Top $1 Billion," *Breaking Defense*, June 19, 2012, http://breakingdefense.com/2012/06/total-cost-to-close-out-cancelled-army-fcs-could-top-1-billion/.
[14] Christopher Pernin, et al., *Lessons from the Army's Future Combat Systems Program*, (Santa Monica, RAND Corporation, 2012), 16.
[15] Marie A. Mak, *Army Combat Vehicles: Industrial Base Study's Approach Met Research Standards* (GAO-15-548) (Washington, DC: U.S. Government Accountability Office, 2015) 18.
[16] 10 USC §2464 (a).
[17] Defined in 10 USC 2460 as, "material maintenance or repair requiring the overhaul, upgrading, or rebuilding of parts, assemblies, or subassemblies, and the testing and reclamation of equipment as necessary, regardless of the source of funds for the maintenance or repair or the location at which the maintenance or repair is performed."
[18] Jack Edwards, *Defense Inventory: Defense Logistics Agency Needs to Expand on Efforts to More Effectively Manage Spare Parts* (GAO-10-469) (Washington, DC: U.S. Government Accountability Office, 2010), 5.
[19] Ibid, 12.
[20] Land Combat Systems, Field Studies (January 29, 2016, February 19, 2016, March 18, 2016, April 3-7, 2016)
[21] Ibid.
[22] Ibid.

[23] Ibid.
[24] Ibid.
[25] Ibid.
[26] Land Combat Systems, Field Studies (April 26-29 2016, May 2-5 2016)
[27] Land Combat Systems, Field Studies (February 19, 2016, March 18, 2016, April 6-7, 2016).
[28] Ibid.
[29] Land Combat Systems, Field Studies (February 19, 2016, March 18, 2016, April 4, 6-7, 2016).
[30] Land Combat Systems, Field Studies (January 29, 2016, February 19, 2016, March 18, 2016, April 4-7, 2016, April 26-29 2016, May 2-5 2016)
[31] Ibid.
[32] Land Combat Systems, Field Studies (March 18, 2016, April 4-6 2016)
[33] Land Combat Systems, Field Studies (January 29, 2016)
[34] Land Combat Systems, Field Studies (January 29, 2016, February 19, 2016, March 18, 2016, April 4-7, 2016).
[35] Ibid.
[36] Francis Fukuyama, "The End of History?," *The National Interest*, no. 16 (Summer 1989): 14.
[37] Scott Gourley, "Wheely Good?" *Land Warfare International* 7, no. 1 (February/March 2015): 12.
[38] The US Army Combat Vehicle Modernization Strategy, Army Capabilities Integration Center, U.S. Army Training and Doctrine Command, September 15, 2015.
[39] *The United States Army's Science and Technology Program for Fiscal Year 2017: Hearing before the Emerging Threats and Capabilities Subcommittee, House Armed Services Committee*, 114th Cong, (February 24, 2016) (statement of Mary J. Miller, Deputy Assistant Secretary of the Army for Research and Technology).
[40] Ibid.
[41] Frances Lussier, *The Army's Ground Combat Vehicle Program and Alternatives*, (Washington, DC: Congressional Budget Office, April 2013).
[42] Anonymous, (not for attribution discussions with US Government Executive), Spring 2016.
[43] Andrew Feickert, *The Army's Multi-Purpose Vehicle: Background and Issues for Congress* (CRD Report No. R43240) (Washington, DC: Congressional Research Service, 2016).
[44] Program Management Office, Advanced Amphibious Assault, Operating and Support (O&S) Cost Analysis for Milestone B Decision Defense Acquisition Board (DAB), November 2015.
[45] Program Management Office, Advanced Amphibious Assault, Request for Proposal Release Decision Brief of Defense Acquisition Board, February 2015.
[46] Anonymous, (not for attribution discussions with DoD Executive), Spring 2016.
[47] Anonymous, (not for attribution discussions with DoD Executive), Spring 2016.
[48] "Navistar Defense Receives $369 Million Vehicle Order To Support Afghanistan Security Forces." *Navistar Press Release*, September 9, 2015, http://www.navistardefense.com/NavistarDefense/newsandevents.

[49] Thomas Held, Bruce Newsome, & Matthew Lewis, *Commonality in Military Equipment: A Framework to Improve Acquisition Decisions,* Santa Monica, CA: Rand Coorporation (2008), 45.

Appendices

Appendix A – Acronyms
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Appendix A: Acronyms

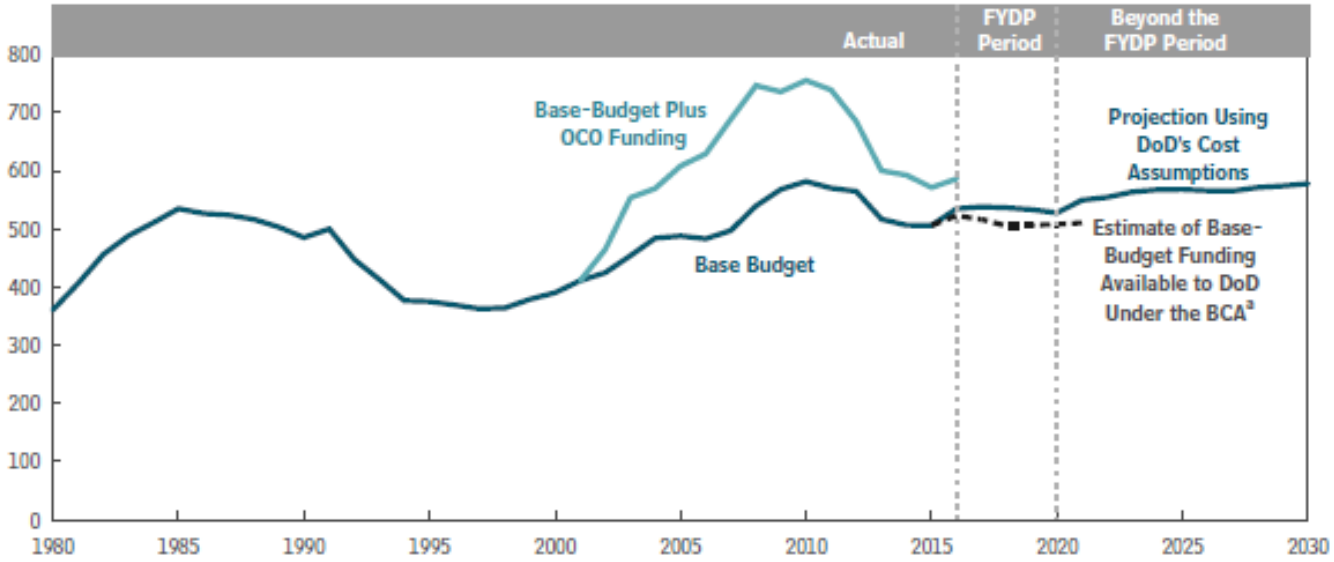
AAV	Amphibious Assault Vehicle
ABCT	Armored Brigade Combat Team
ACE	Armored Combat Earthmover
ACV	Amphibious Combat Vehicle
AECA	Arms Export Control ACT
AMG	American Motors General
AMPV	Armored Multi-Purpose Vehicle
ANAD	Anniston Army Depot
AWCF	Army Working Capital Fund
BAE	British Aerospace Engineering Systems
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
IB	Industrial Base

IR&D	Independent Research and Development
IFV	Infantry Fighting Vehicle
ITAR	International Trade 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
MLRS	Multiple Launch Rocket System
MPC	Marine Personnel Carrier
MRAP	Mine Resistant Ambush Protected
M-ATV	MRAP All-Terrain Vehicle
MSR	Minimum Sustainment Rate
MTV	Medium Tactical Vehicle
NAV	Navistar
NATO	North Atlantic Treaty Organization
NSS	National Security Strategy
OEM	Original Equipment Manufacturer
OIB	Organic Industrial Base
O&M	Operations & Maintenance
OSK	Oshkosh Defense
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
R&D	Research & Development
SLEP	Service Life Extension
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

Land Combat System (LCS) Vehicle Classes

Tactical Wheeled Vehicles (TWV)	Protected Vehicles (PV)	Combat Vehicles (CV)
Light Trucks High Mobility Multipurpose Wheeled Vehicle (HMMWV)	**Mine Resistant Ambush Protected (MRAP)**	**Armored Personnel Carriers (APC)**
USSOCOM Ground Mobility Vehicle (GMV)	Caiman (4x4), (6x6)	Stryker, M113
Joint Light Tactical Vehicle (JLTV)	RG-31, 33 (4x4), (6x6)	**Amphibious Assault Vehicles (AAV)**
Medium Trucks Family of Medium Tactical Vehicles (FMTV)	Cougar (4x4), (6x6)	AAV, Amphibious Expeditionary Vehicle (AEV) (Developmental)
Medium Tactical Vehicle Replacement (MTVR)	MaxxPro (4x4)	**Self-Propelled Artillery (SP)** M-109
Heavy Trucks Heavy Expanded Mobility Tactical Trucks (HEMTT)	MATV (4x4)	**Infantry Figthing Vehicles (IFV)** M-2 Bradley
Palletized Loading System (PLS)		
Heavy Equipment Transporter (HET)		**Main Battle Tanks (MBT)** M-1 Abrams

Historical Funding for DoD's Activities and Projected Costs of DoD's Plans



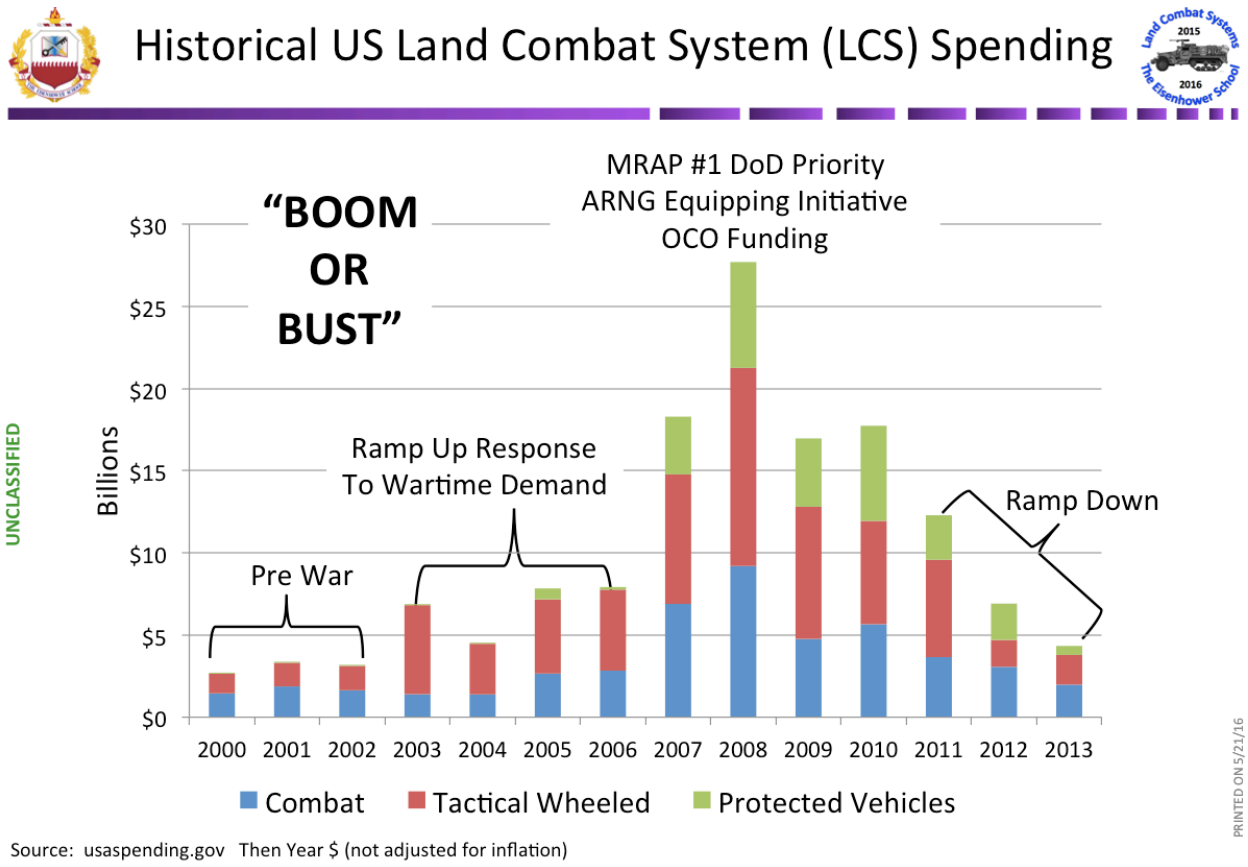
Source: Congressional Budget Office.

Notes: Base-budget data include supplemental and emergency funding before 2002. For 2002 to 2016, supplemental and emergency funding for overseas contingency operations, such as those in Afghanistan and Iraq, and for other purposes is shown separately from the base-budget data. No OCO funding is shown for 2017 and later.

BCA = Budget Control Act of 2011; DoD = Department of Defense; FYDP = Future Years Defense Program; FYDP period = 2016 through 2020, the period for which DoD's plans are fully specified; OCO = overseas contingency operations.

a. This estimate incorporates the assumption that the funding available to DoD would be equal to the BCA's limit for national defense minus the Administration's estimates for national defense funding for agencies other than DoD (that is, funding for the Department of Energy's nuclear weapons activities, intelligence-related activities, and the national security elements of the Departments of Commerce, Justice, and Homeland Security, and several independent agencies).

Congressional Budget Office, Long-Term Implications of the 2016 Future Years Defense Program, (January 2016)



United States Land Combat System Spending (2000-2013)

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 Tactial Vehicle
(FMTV)

Medium Tactical Vehicle Replacement
(MTVR)

Tactical Wheeled Vehicles (Heavy Trucks)

Heavy Expanded Mobility Tactical Truck (HEMMT)

Heavy Equipment Transporter (HET)

Protected Vehicles (4X4)

Caiman

RG-31

Cougar

MRAP All Terrain Vehicle (M-ATV)

Protected Vehicles (6X6)

Caiman

RG-33

Cougar

Combat Vehicle (CV)
Infantry Fighting Vehicle (IFV) / Tank

M2 Bradley

M1 Abrams

Combat Vehicles (CV)
Armored Personnel Carriers (APC)

M113

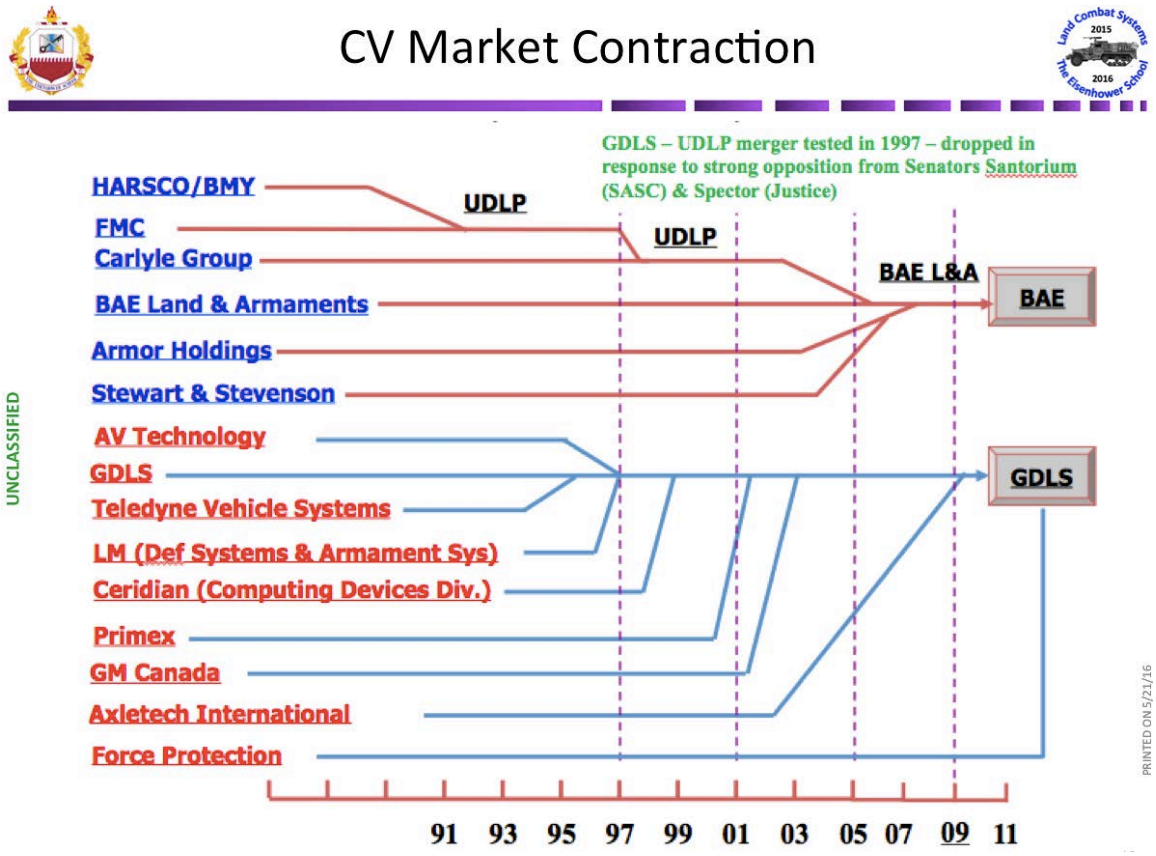
Stryker

Combat Vehicle (CV)
Amphibious Assault Vehicles (AAV)

AAV-7

Amphibious Combat Vehicle (ACV) 1.1 EMD Prototype

Amphibious Combat Vehicle (ACV) 1.1 EMD Prototype


CV Market Contraction
GDLS – UDLP merger tested in 1997 – dropped in response to strong opposition from Senators Santorium (SASC) & Spector (Justice)
HARSCO/BMY
FMC
Carlyle Group
BAE Land & Armaments
Armor Holdings
Stewart & Stevenson
AV Technology
GDLS
Teledyne Vehicle Systems
LM (Def Systems & Armament Sys)
Ceridian (Computing Devices Div.)
Primex
GM Canada
Axletech International
Force Protection
UDLP
UDLP
BAE L&A
BAE
GDLS
91 93 95 97 99 01 03 05 07 09 11
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Technology Readiness Level (TRL)

Technology Readiness Levels (TRL) are a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process. They are determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities. TRL are based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform, discussions of technical maturity across different types of technologies. Decision authorities will consider the recommended TRLs when assessing program risk. The DoD TRL's are defined in the table below:

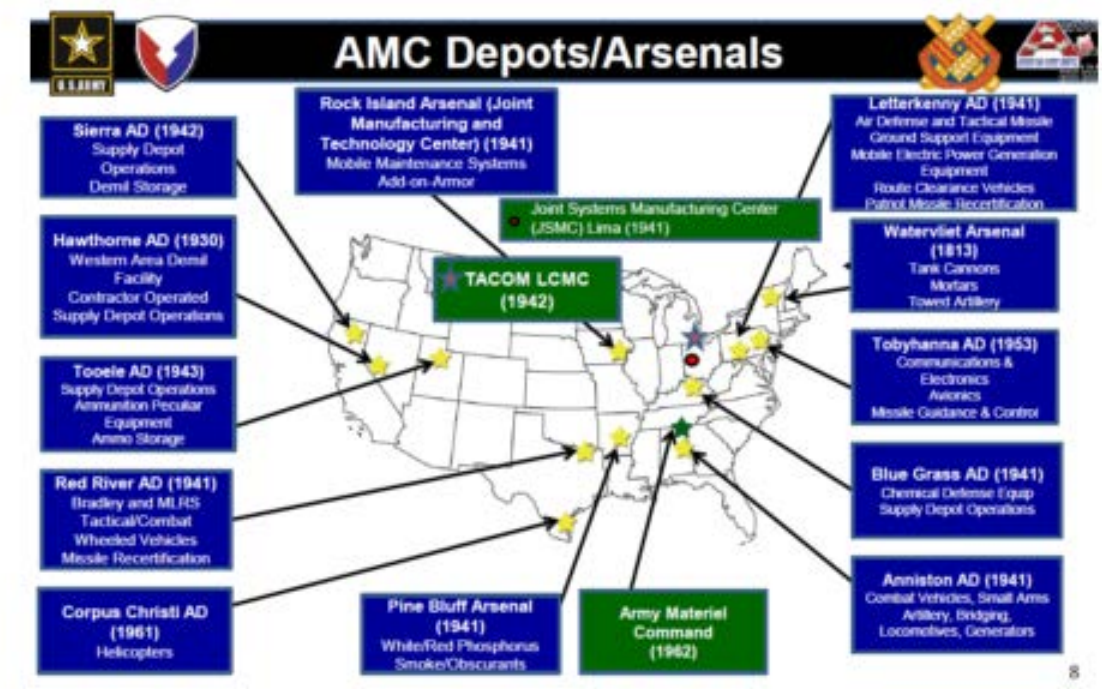
Level	Definition	DoD DAG Description
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5	Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness.
7	System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space.
8	Actual system completed and	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the

	qualified through test and demonstration.	end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.
Defense Acquisition Guidebook (DAG) – Chapter 10		

The primary systems engineering objective is to gain sufficient technical knowledge to develop the program's System Requirements Document (SRD) and to verify that the system solution(s) required technology is sufficiently mature, has a TRL 6 or above, before proceeding into an end-item design or Milestone B.

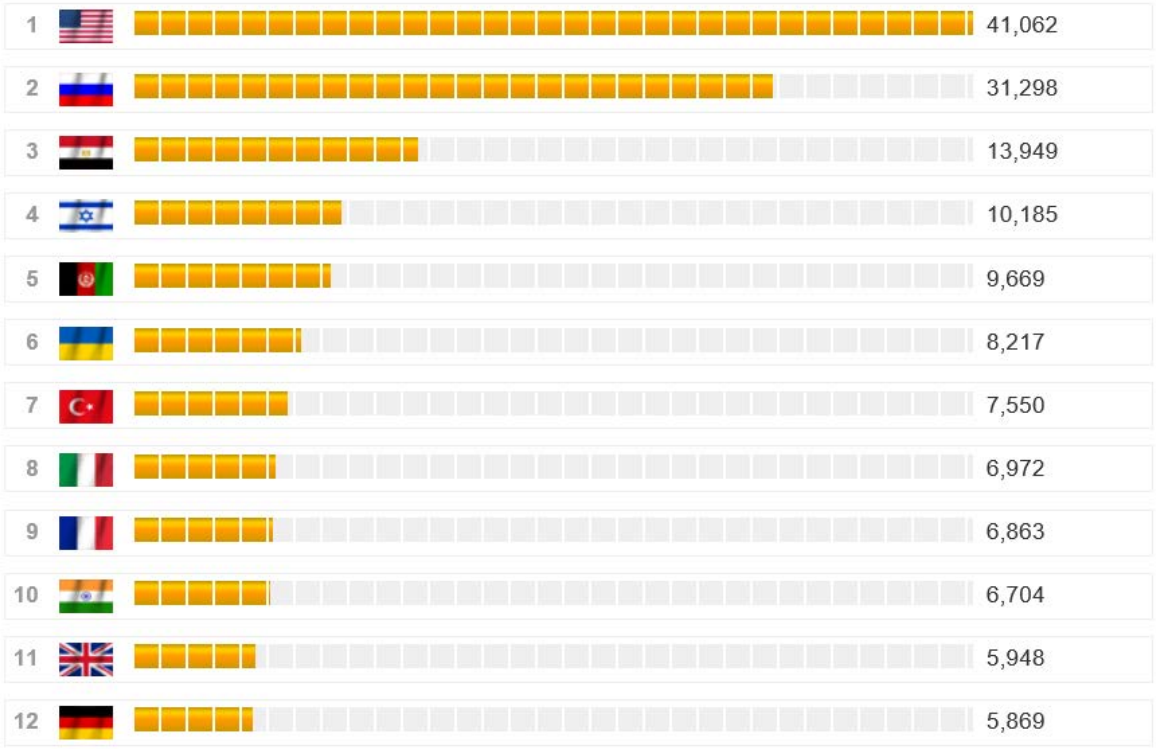
Citation

1. http://www.acqnotes.com/acqnote/tasks/technology-readiness-level, accessed May 11, 2016

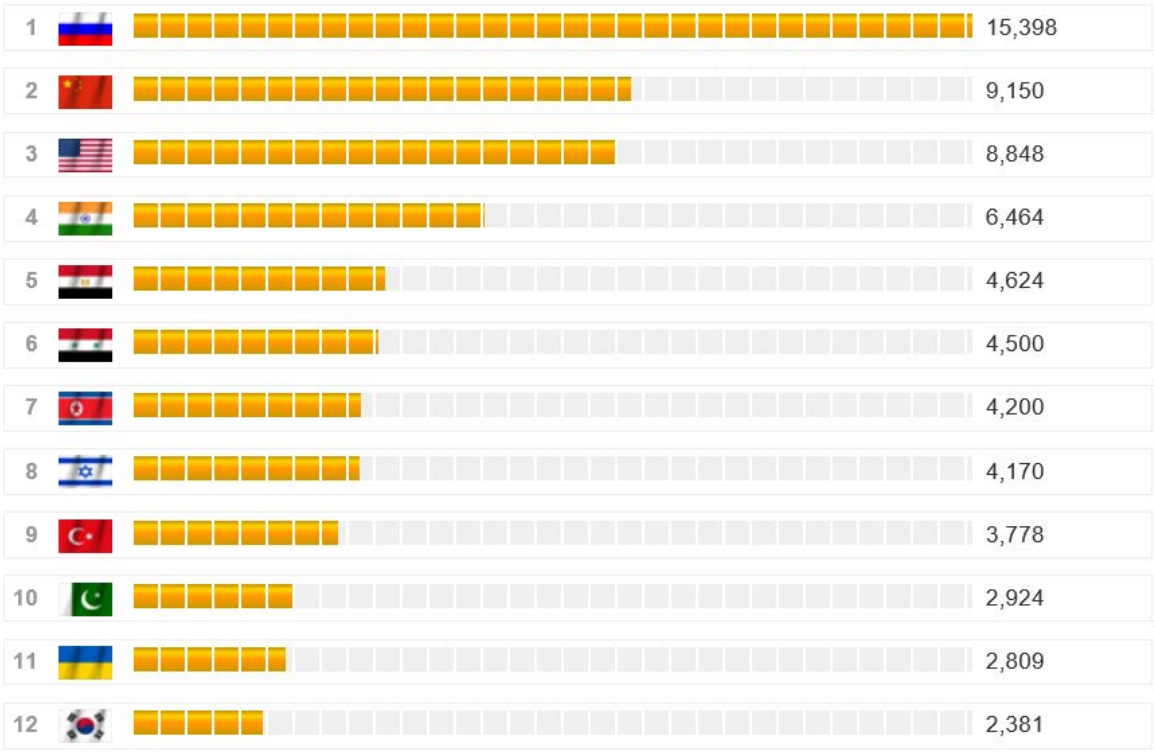

AMC Depots/Arsenals
Sierra AD (1942)
Supply Depot Operations
Demil Storage
Rock Island Arsenal (Joint Manufacturing and Technology Center) (1941)
Mobile Maintenance Systems
Add-on-Armor
Letterkenny AD (1941)
Air Defense and Tactical Missile
Ground Support Equipment
Mobile Electric Power Generation Equipment
Route Clearance Vehicles
Patriot Missile Recertification
Joint Systems Manufacturing Center (JSMC) Lima (1941)
Hawthorne AD (1930)
Western Area Demil Facility
Contractor Operated Supply Depot Operations
TACOM LCMC (1942)
Watervliet Arsenal (1813)
Tank Cannons
Mortars
Towed Artillery
Tooele AD (1943)
Supply Depot Operations
Ammunition Peculiar Equipment
Ammo Storage
Tobyhanna AD (1953)
Communications & Electronics
Avionics
Missile Guidance & Control
Red River AD (1941)
Bradley and MLRS Tactical/Combat Wheeled Vehicles
Missile Recertification
Blue Grass AD (1941)
Chemical Defense Equip
Supply Depot Operations
Corpus Christi AD (1961)
Helicopters
Pine Bluff Arsenal (1941)
White/Red Phosphorus Smoke/Obscurants
Army Materiel Command (1962)
Anniston AD (1941)
Combat Vehicles, Small Arms Artillery, Bridging, Locomotives, Generators

Appendix I (EU CV Firms and Products)

APCs and IFVs (wheeled and tracked)



Main Battle Tanks

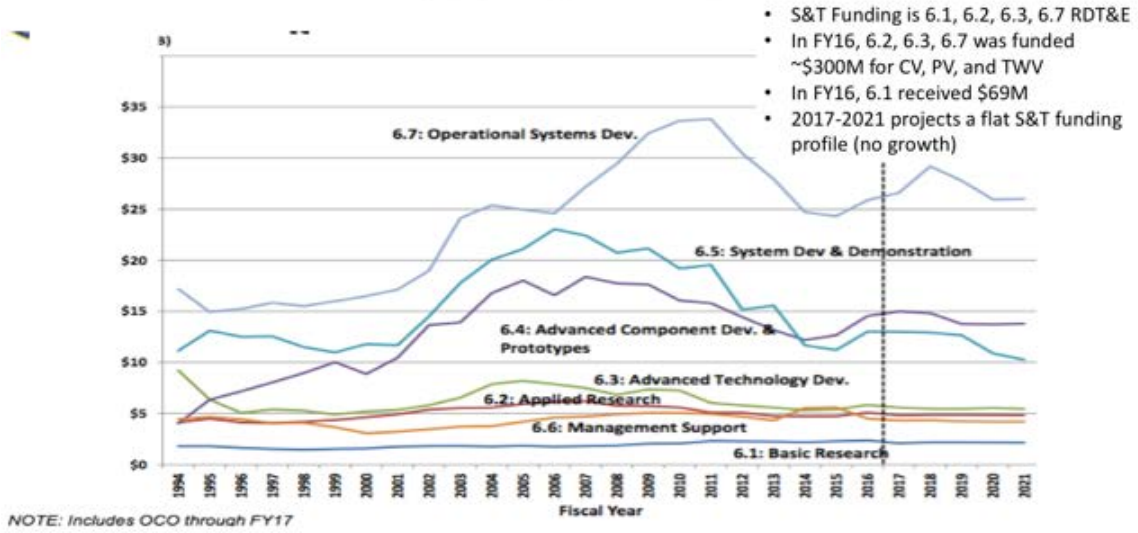


Source: http://www.gobalfirepower.com

U.S. – European Combat Vehicle Comparison

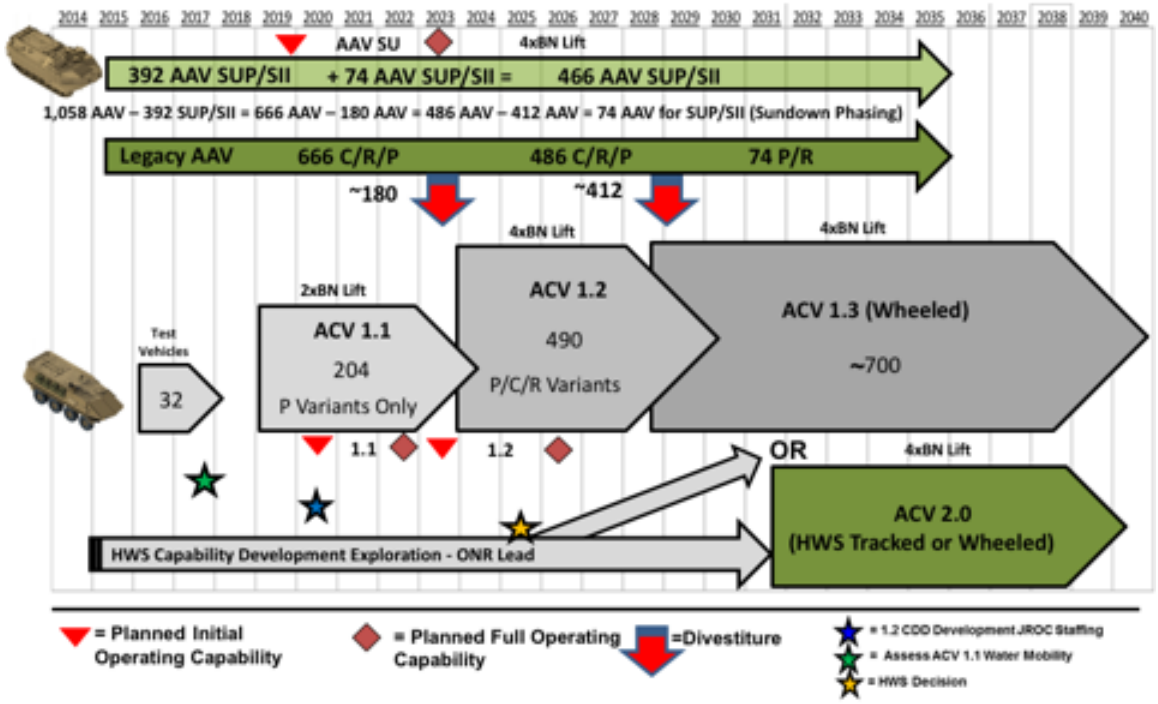
	US	Europe
Tanks	M1 Series	Leopard II (KMW, Germany) Challenger II (BAE/Vickers, UK) LeClerc (Nexter, France) Ariete (Oto Melara-Iveco, Italy) Altay (Otokar/Hyundai, Turkey)
Tracked Infantry Fighting Vehicles	ADD PHOTOS Bradley Series AAV	AMX-10P (Nexter, France) Puma (KMW, German) Ulan (GDELS Steyr, Austria) Dardo (Oto Melara-Iveco, Italy) Warrior (BAE/Alvis, UK) CV-90 (BAE Hagglunds, Sweden)
Wheeled Armored Vehicles	Stryker (Piranha III) LAV (Piranha I)	Pandur (GDELS Steyr, Austria) Piranha (GDELS Mowag, Swiss) AMV (Patria, Finland) Freccia (Oto Melara-Iveco, Italy) Boxer (KMW, Germany) VBCI (Nexter, France) PARS (FNSS, Turkey)

S&T FUNDING



NOTE: Includes OCO through FY17

AA Modernization Phasing Overview



UNITED STATES EXPORT CONTROL REFORM INITIATIVE

Overview

On April 16, 2013, the U.S. Departments of Commerce and State published final rules describing the initial implementation of Export Control Reform (ECR). These final rules fundamentally reform the U.S. export control system by changing the jurisdiction of thousands of military items, mostly parts and components, that do not provide a critical military or intelligence capability. Such items will move from the International Traffic in Arms Regulations (ITAR), which are administered by the State Department, to the Export Administration Regulations (EAR), which are administered by the Commerce Department.

Items transferring from the ITAR's U.S. Munitions List (USML) to the EAR's Commerce Control List (CCL) are identified under new Export Control Classification Numbers (ECCNs), known as the 600 series. The first category groups transitioned on October 15, 2013, and additional category groups will transition throughout 2014 and 2015. The items that have transitioned or are scheduled to transition are as follows:

Item Group	600 Series	Effective
Aircraft	9Y610	10/15/13
Gas turbine engines	9Y619	10/15/13
Vessels	8Y609	1/6/14
Vehicles	0Y606	1/6/14
Materials/Misc.	0Y617	1/6/14

Submersibles	8Y620	1/6/14
Rad-hard ICs*	9Y515	6/27/14
Launch vehicles	0Y604 9Y604	7/1/14
Energetic materials	1Y608	7/1/14
Training equip.	0Y614	7/1/14
Protective equip.	1Y613	7/1/14
Satellites*	9Y515	11/10/14
Electronics	3Y611 9Y620	12/30/14

Impact

Reducing Jurisdiction and Classification Confusion

Under ECR, military items meriting the strictest controls will be enumerated as specifically as possible on the USML by using performance characteristics or other specifications. When items cannot be specifically enumerated, they will be described as items "specially designed" for another military item. This construct will use a new definition for the term "specially designed," which uses a catch-and-release construct where one answers a series of yes or no questions to determine if an item is "specially designed." The same enumeration process and "specially designed" construct will be used for 600 series items on the CCL. By following this approach, ECR will allow reviewers to use more objective criteria rather than more subjective factors like design intent.

Tailoring Controls: No More One-Size- Fits-All Approach

Items subject to the ITAR are generally all subject to the same worldwide controls with little variation and few country-based exemptions. However, controls over items subject to the EAR can be tailored depending on the sensitivity of the item, country of destination, end use, and end user.

Most 600 series items will require a license to all countries except Canada, but many will be eligible for license exceptions. This will avoid the need for prior approval from the U.S. Government for transactions of less concern, such as trade with U.S. allies. By tailoring controls, ECR will allow for greater interoperability among the U.S., NATO countries, and other allied countries.

Some 600 series items are identified as ".y" items and only require a license to China,

STA-Authorized Destinations

Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark,

Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia,

Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal,

Romania, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey,

and the United Kingdom

Cuba, Iran, North Korea, Russia, Sudan, Syria, and Venezuela. These items are extraordinarily low-level parts, such as windshield wipers specially designed for military aircraft. By focusing controls on items of greater sensitivity, the U.S. Government will be able to more efficiently direct its resources to reviewing items providing greater military transactions of greater concern.

Enhancing Interoperability and Cooperation with Allies

Most 600 series items will be eligible for License Exception Strategic Trade Authorization (STA), which allows for license-free exports and reexports to 36 countries for ultimate end use by the country's armed forces, police, paramilitary, law enforcement, customs, correctional, fire, or search and rescue agency.

STA Checklist:

- ✓ ·Determine ECCN, end use, and end user eligibility
- ✓ ·Confirm all foreign parties have been listed on a previously approved license or other approval issued by the Commerce or State Departments

- ✓ ·Provide ultimate consignee with the ECCN
- ✓ ·Obtain Prior Consignee Statement from ultimate consignee prior to export or reexport
- ✓ ·Notify consignee of STA shipment
- ✓ ·Keep records of STA shipment

Providing Greater Predictability in Maintaining Customer Service

Most 600 series parts and components may be exported under a license exception to replace defective or worn parts and components abroad, as well as to return items serviced in the U.S. to foreign customers. Also, U.S. companies may temporarily import 600 series items into the U.S. for servicing without needing to obtain a license or use an exemption.

In addition, if a customer requests a sample 600 series commodity, it is possible for the U.S. company to export the sample without needing a license. Shipments of most 600 series items valued at $1500 or below may be exported under a license exception to many destinations.

Aiding the U.S. Defense Industrial Base

Under the ITAR, military items incorporated into a foreign-made item will subject that item to ITAR control, even if the item is commercial. Thus, such foreign-made items would require reexport or retransfer authorization from the U.S. in addition to any local country requirements. Because of this "see-through" rule, foreign companies have an incentive to design out or avoid U.S. content, which potentially damages the U.S. defense industrial base.

Items subject to the EAR are generally not subject to this see-through rule. If 600 series items (excluding .y items) are incorporated into a foreign-made item, the foreign-made item will not be subject to U.S. jurisdiction under the EAR so long as: (1) the value of the controlled U.S. content comprises 25% or less of the total value of the item, and (2) the item will not be destined for a country subject to a U.S. arms embargo. If only 600 series .y items are incorporated into a foreign-made item, the foreign-made item will not be subject to U.S. jurisdiction under the EAR so long as the item will not be destined for China, Cuba, Iran, North Korea, Syria, or Sudan.

Allowing for Flexibility in Obtaining Licenses or Other Approvals

Organizations having State Department licenses or other approvals for 600 series items may be able to continue using such authorizations in accordance with the State Department's transition plan. In addition, for future transactions involving 600 series items that will be used in or with military items remaining on the ITAR, applicants may submit one license application to the State Department for the entire transaction. This will

save applicants from having to submit a license application to the State Department for the ITAR items and a separate license application to the Commerce Department for the 600 series items.

Additional Information

Latest ECR Updates: www.export.gov/ecr U.S. Department of Commerce
Agency website: www.bis.doc.gov
Decision tools: www.bis.doc.gov/index.php/decision-tree-tools
Export Administration Regulations: 15 C.F.R. Parts 730-774
U.S. Department of State
Agency website: www.pmddtc.state.gov
International Traffic in Arms Regulations: 22 C.F.R. Parts 120-130

[50] SOURCE https://webcache.googleusercontent.com/search?q=cache:9i5BylybVYEJ:https://www.bis.doc.gov/index.php/forms-documents/doc_download/1094-ecr-brochure-nov-14-2014+&cd=3&hl=en&ct=clnk&gl=us (accessed May 13th, 201