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Industry Study

Final Report
Land Combat Systems Industry

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LAND COMBAT SYSTEMS 2009

ABSTRACT: There has been significant change in land warfare as ground forces have simultaneously entered a network-centric age, an era of insurgency, and encountered changed players in the international system. To adapt to these changes, both industry and the military evolved in both requirements determination, development of new products, and rapid modifications of existing vehicles. It is the evolved military ground equipment required in these theaters, and industry's role in provisioning them, that motivated this evaluation of the LCS industry.

The Land Combat Systems Industry Study spent four months visiting manufacturers, policy makers, and depots to compile this report. Over the course of the study while researching the Structure, Conduct and Performance of the industry, the seminar developed the following Major Findings on strategic issues identified and reported in report sections that follow below.

- Reform the requirements generation process to become more responsive and agile in the face of changes in enemy tactics and evolving US tactics.
- Partnerships between firms and within firms (labor and management) are crucial to agile response to changing requirements.
- There was sufficient surge capacity within the LCS industrial base to meet the demands of the campaigns in Iraq and Afghanistan.
- Public-Private Partnerships and joint-ventures were expanded during the last 4-6 years illustrating the globalized nature of the industry and the evolving role of government-owned depots in production of combat and tactical vehicles.
- Every vehicle is now a "combat vehicle" that sports a measure of armor protection and weapons.
- Information technology is expanding into the ground vehicle fleet at an exponential rate; including situational awareness, C2, and electronic-counter measures systems.

The hallmark of the LCS industry production capabilities over the past five years has been flexibility and agility. The industry responded quickly to produce both modifications to existing vehicles and new vehicles to meet the changing requirements of the DoD forces in the counterinsurgency environment during the period 2003-2009. Equipping the ground forces from the individual Soldier/Marine/Airman all the way to major armored combat formations evolved continuously during the campaigns in the Iraq and Afghanistan Theaters with the industry responding to doctrinal and tactical changes. The LCS industry underwent a similar transformation through vertical integration and consolidation, as well as internal transformation to become more agile and response to constantly developing requirements

- Globalized supply chain constrained by 20th century government policies (e.g. "Buy America", ITAR, etc); it is often second-tier suppliers that are most affected.
- Sufficient capacity existed to surge in both industry and government-owned production facilities to meet the demands of the Iraq and Afghanistan Theaters in the Long War
- Vertical integration within the industry has generated complex teaming and joint venture relationships that can be characterized with the terms “Coopertition” (a joint-venture between competitors) and “Competemies” (individual business units within the same company competing for the same contract).

- Armoring and arming vehicles not previously classified as "combat" vehicles generated a need for lightweight after-market armoring solutions, and new vehicles.

Clearly, the changes in industrial capacity and production methods were not merely a response to the globalized environment, but a response to DoD requirements generated through two parallel processes. The traditional "industrial" process generated some requirements through long-term planning and doctrinal thought. However, some requirements for vehicles and vehicle systems were emergent responses to rapidly changing enemy tactics and weapons. These parallel requirements generation processes each produced weapon systems suited to particular tasks and defeating particular threats.

For example, the Textron Marine and Land Systems' Armored Security Vehicle (ASV) and the General Dynamics Land Systems Stryker were both developed to fit niche requirements through the PPBE over a long term. These combat vehicles were "programs of record" that were programmed and funded for a given purpose, and adapted to meet the demands of counterinsurgencies in Iraq and Afghanistan. In contrast, the Mine Resistant Ambush Protected family of vehicles and up-armored High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) modifications were rapid responses by industry and the depots to adjust to emergent threats.

Industry responded to these changes in requirements generation and the coming constriction in DoD procurement spending through innovative joint ventures and public-private partnerships that attempted to maximize workforce employment, minimize cost, and employ firms in their "strength" (e.g. heavy metal or commercial truck manufacturing). Furthermore, the dynamic environment saw new entries into the market with aerospace companies teaming with truck companies for the Joint Light Tactical Vehicle (JLTV) prototypes and multiple manufactures working together to produce MRAP trucks.

DoD leaders and procurement officials must be mindful of these structural changes in the industry as they bear directly on the viability of the defense industrial base, and the ability of industry and government facilities to respond to the volatile, complex, and interdependent 21st century security environment.

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PLACES VISITED

Domestic

PM Expeditionary Fighting Vehicle - Woodbridge, VA
PM JLTV - Woodbridge, VA
PM MRAP - Woodbridge, VA
Anniston Army Depot - Anniston, AL
GDLS Anniston Operations (Stryker Assembly Plant) - Anniston, AL
Aberdeen Test Center - Aberdeen, MD
BAE Ground Systems Division - York, PA
Textron Marine & Land Systems - New Orleans, LA
MTU Detroit Diesel - Detroit, MI
General Dynamics Land Systems - Sterling Heights, MI
Joint Systems Manufacturing Center - Lima, OH
Allison Transmission - Indianapolis, IN
AM General - South Bend, IN

International

GDELS Steyr-Daimler-Puch Spezialfahrzeug - Vienna, Austria
MAN Österreich - Vienna, Austria
MAN Nutzfahrzeuge AG- Munich, Germany
Renk Transmissions - Augsburg, Germany
Krauss-Meffei-Wegmann - Munich, Germany
Nexter Systems - Paris, France
Panhard General Defense - Paris, France
European Defense Agency - Brussels, Belgium
European Commission - Brussels, Belgium
U.S. Mission to the EU - Brussels, Belgium
GICAT - Paris, France

INTRODUCTION

Motivation for Studying the Land Combat Systems (LCS) Industry

During the first decade of the 21st Century, the "American Way of War" has undergone significant change as land warfare simultaneously entered a network-centric age, an era of insurgency, and encountered changed players in the international system. Military forces were required to adapt to these changes while conducting simultaneous campaigns of varying size and intensity in theaters as diverse as the Philippines, Iraq, Afghanistan, and the Horn of Africa. During the course of these campaigns military forces have adapted their doctrine, tactics, and equipment, especially in Iraq and Afghanistan. It is the evolved military ground equipment required in these theaters, and industry's role in provisioning them, that motivated this evaluation of the LCS industry.

The current campaigns in both Iraq and Afghanistan are characterized by rapidly changing enemy tactics, demanding an historic level of agility from the industrial base and the Pentagon. As the fight in Iraq morphed from traditional force-on-force to counter-insurgency, so did the requirement for land combat systems. The LCS industry responded to Pentagon requirements with increased participation in the industry, realignment among participants within the industry, upgrades of existing systems, new protection measures, and new vehicles military forces fighting the Long War. Each change in requirements will drive change in the supporting government and private LCS industries, expanding and contracting as appropriate.

Thus far, the defense industrial base has been able to respond to changes in warfighting requirements. The war-related surge in industry output is instructive as it demonstrates the function of the requirements generation process and the corresponding industrial base response.[1] There are a number of lessons to be learned from recent campaigns that, if absorbed, can facilitate optimal decision making in the LCS arena of the future.

THE INDUSTRY DEFINED

The “LCS Industry” refers to that part of the industry manufacturing military armored vehicles, combat tanks, specialized components for combat tanks, and self- propelled weapons. The major products of this industry are primarily tanks and parts, tracked and wheeled combat vehicles, armored utility vehicles and parts.[2] The largest segment of this industry market is its Products and Services segment, with tanks and parts accounting for 47%. Tracked and Wheeled Vehicles and Armored Utility Vehicles and parts comprise 38%, while self-propelled weapons, parts and components make up the remaining 15 per cent.[3] The numbers of LCS manufacturers are increasing worldwide as a result of economic globalization. Domestic and international exports in this industry are modest but important while imports are medium and increasing. The main imports in 2007 came from Canada, Israel, and Norway, and the exports went to Egypt, Israel and Australia. Demand in this segment can be erratic, affected by political conditions, international supply tenders as well as other factors.[4] Competition in the industry is typically low and steady, but affected by increased LCS funding along with the increased demand for support vehicles incentivizing new entrants into the LCS markets. Limited competition is typically a result of high entry barrier costs, and a required familiarity by industry with the military and acquisition processes. Internal competition, however, with incumbent firms is high,

increasingly high as external providers from international markets and subsidiaries add pressure.[5] Supplemental budgets resulting from the current wars, along with the increased system of system complexity of warfighter requirements, have incentivized partnerships and other liaisons with nontraditional LCS suppliers both domestic and international.

The key findings from this study are different from previous studies of the industry as the strategic environment has changed significantly and become increasingly concentrated since 2008. Fragile and changing markets, the financial crisis, declining government budgets across Europe and the US, evolving doctrine(s), and continued consolidation in the industry are hallmarks of the LCS industry in 2009. The LCS industry in the 21st Century is an evolving industry in a changed world.

Overview of US-European Differences

Two major differences between the US and European LCS industries stand out: the American separation of powers vs. the European parliamentary system, and the international nature of US companies vs. the "national" defense companies in Europe.

Structurally, the form of government on each of the two continents generates an industry that performs in a particular manner. In the American system, the separation of power between the Congress and the President generates an industry structure that necessarily leans more heavily toward political efficiency rather than fiscal or programmatic efficiency. Production in the US is often distributed geographically across multiple states to maximize votes in Congress for funding, rather than for the fastest, most economical, optimal design, or most efficient production. One-year budget authorizations cause uncertainty and gross financial inefficiencies for production firms and government program managers alike. Neither can be certain that their weapon system funding will be authorized and appropriated on schedule as planned or become the next sacrifice on the altar of political efficiency and/or fiscal expediency. As a result, the available dollars determines both the capability to be delivered and how the program executes. The system tends to preserve programs that are on the technical cutting edge versus needed upgrades or sustainment funding, and defense companies are constantly lobbying for their products to the Congress and within the executive staffs. The parliamentary systems of Europe provide for a bit more funding stability than does the American system, but with less incentive for innovation. Programs are planned for and budgeted by phase, however, the modest budgets of the EU and fairly limited strategic goals constrain systems development in quantity (numbers of new programs) as well as technological advancement

While the American defense industry struggles with competing business models, the European defense industry appears to have reached a steady state. Industry on the Continent is often described as "European", but there are still many nation states within the EU with a fragile defense alignment. There is nothing approaching a single European defense strategy guiding procurement. Furthermore, there exists horizontal integration in Europe among the defense firms in the LCS industry, but not to the same extent that the US has experienced. Since there are multiple markets, i.e. national armies/buyers within the EU community, more defense companies are the result. Multiple buyers, without a unifying EU Defense Acquisition Strategy, do little to unify the LCS industry, standardize interoperability or establish acquisition efficiencies. Another major difference between the two continents is the global nature of firms now supporting both the EU and US LCS requirements, functioning under US rules in the US and EU rules in the EU. European companies are expanding into US markets through partnerships with and acquisition of US companies. Many of those same companies are having difficulty

maintaining sales in their own countries as national defense budgets contract, leaving the US market as the place "where the money is," even for European companies like BAE and MTU. These newly global firms, dominated by GDLS and BAE L&A, are supported by a complex global network of interconnected suppliers. Distinctions between the various industries are becoming blurred.

Defining the Study

This study of LCS is presented against the backdrop of the previous introductory material; motivation, definition, and comparison to the European LCS industry. First, the questions developed to probe strategic issues within the LCS industry are offered, and then the industry is presented within the context of a structure, conduct, performance framework, followed by a discussion of the major findings of the effort.

The LCS Industry Study team conducted its research through discussions from various LCS industry representatives, visits to depots, testing facilities, major LCS producers, and component suppliers to the LCS industry. International visits included government agencies, major LCS producers, and component suppliers in Austria, Germany, France and Belgium.

Strategic Issues and Questions

The following questions were developed to guide interaction during domestic and international LCS visits. They were intended to draw out information relevant to the strategic issues faced the US as it addresses national security from a LCS perspective.

- What impact have the ongoing wars in Iraq and Afghanistan had on the DoD demand for LCS products?
- How has the US industrial base responded to the change in DoD demand?
- What impact has the ongoing engagement and economic downturn had on the modernization plans of the US military?
- How do the US and EU LCS compare in their structure, response to current engagements and the economic downturn?
- Are the government processes affecting acquisition (requirements, contracting, budgeting, etc.) sufficiently agile to support the military response to changes in enemy tactics and materiel?

STRUCTURE, CONDUCT, & PERFORMANCE OF THE LAND COMBAT SYSTEMS INDUSTRY

The LCS industry is a significant contributor to the defense of the nation. As such it is considered to be a "public good," providing a service that benefits all citizens. Government acts as a monopsony, the sole purchaser of the LCS capability component of the nation’s security. The US Department of Defense is the single largest consumer of the LCS products in the world, with more of an LCS budget than that of the rest of the world buyers combined.

The US government acts as buyer, regulator and provider within the LCS Industry. As a monopsony buyer, the government wields significant buying power, shaping the response of the LCS Industry. How much buying power, and how much regulation guiding it, is a reflection of

the governmental structure, the checks and balances of power of the system. The unusual role of provider is a reflection of the necessity to preserve the ability of the nation to provide the national security. In this role the government ensures the sufficiency of the nation to respond to a demand that could potentially outstrip the available capability within the commercial market.

While consumers within a market normally seek to maximize utility and suppliers the return to their shareholders, the unique structure of government blurs these seemingly clear economic objectives. The purchasing decisions of the US government are grounded in the balance of powers exercised by its three competing branches. The method, quantity, selection, and location of the manufacturer are all the result of compromise among competing interest groups within the government and industry, each with its own set of objectives. The resulting purchases then cannot, therefore, be expected to reflect the best value available for the price, a standard that is inevitably applied retrospectively by both government and industry officials.

Legislation such as the Buy American, Small Business, and Procurement Integrity Acts, as well as various other laws safeguarding American taxpayer, business, and general economic interests, all affect how government and industry interact. Specific acquisition legislation, regulating federal purchasing including the Federal Acquisition Streamlining Act of 1994 (FASA) emphasized a preference for commercial items and procedures where possible and conflicted with other regulations already in place, and the Federal Acquisition Regulation (FAR-Part 12) was amended to include commercial friendly acquisition. Taken together, all of the regulations associated with buying LCS often ensure a less than timely or best value purchase made in support of national security objectives.

While regulation plays its part in the acquisition of LCS, even more basic is the availability of the dollars for new systems. The past six years of continuous conflict has significantly impacted LCS funding availability, with 2008 LCS spending at a level quadruple that of 2002. This marked increase in funding energized not only the Congress (and their constituencies), but also the commercial sector and new firms entered what had been a previously fairly level/static market. Firms entering the LCS sector found themselves in a unique market, characterized by a mix of ownership arrangements. The LCS consists of government owned/government operated (GOGO) arsenals and depots that are relics of the 20th Century world wars, some with commercial tenants (GOCO)[6] related to the government through Public-Private Partnership taking advantage of the advantages of collocation. There are other entities like the Joint Service Manufacturing Center (JSMC) with an Army/Automotive industry legacy, contractor facilities furnished with government equipment, and fully owned commercial ventures. Even some aerospace firms entered the market during the "war surge boom", pulled in by new technologically advanced LCS systems. Regardless of the organizational configuration all of these LCS participants now operate in an increasingly global environment where their own partnerships, engineering expertise, and supply chains can and do cross borders.

Probably most determinative of the configuration of LCS is the philosophy of the nation, combined with the nature of the conflicts it's engaged in. The low tolerance of the US Congress and populace for wartime casualties drove requirements for precision guided weapons and low collateral damage finds its' LCS analogy in a survivability requirement for all ground vehicles that has made tactical support vehicles into heavy, complex combat vehicles and revived a previously waning commitment to heavy tracked armored vehicles. A change in terrain as US troops move from Iraq to Afghanistan creates even more challenging requirements for the LCS industry. This less developed country requires survivable vehicles of additional mobility without

additional weight or a loss of other functionalities. As LCS budgets decrease and US philosophy remains constant, additional requirements become increasingly less affordable and overall capacity that can be purchased diminishes. LCS participants will find themselves in an increasingly concentrated industry much less enticing than it was a short time ago.

DISCUSSION OF MAJOR FINDINGS

Health of the Industry and Outlook

The overall health of the LCS industry in the United States remains strong, but somewhat fragile. Two large global firms are strong forces in the market (BAE and GDLS), and a host of smaller companies have been able to stay in business so far on the strength of contracts for work supporting the campaigns in Iraq and Afghanistan. Some of the smaller business entities have aligned with larger ones through either joint ventures or private-public partnerships. In this manner they are able to leverage the resources and reach of the larger businesses (or depots) and compete in the LCS sector (e.g. Force Protection partnered with GDLS to surge production on the MRAP).[7] Moves to increase leverage through public-private partnerships were not limited to small businesses. GDLS realized market advantage through proximity gained by partnership with the Anniston Army Depot, and is collocated with its government partner on the depot campus. In the face of global economic crisis and eventual drawdown of the forces in Iraq and Afghanistan, it remains to be seen how many firms remain viable. The economic downturn and eventual drawdown will compel a reprioritization of defense spending. Already, as of May 2009, announcements of reprioritization and cancellation of programs have begun. Most relevant to LCS is the cancellation of the Future Combat System (FCS) manned ground vehicles (MGV). As of this writing, the Army is quickly revamping acquisition plans to recover from the cancelation the FCS MGV.[8]

The unit cost of land combat vehicles has grown dramatically during the course of the Iraq/Afghanistan campaigns. "Tactical" vehicles are now being up-armored and include systems like mounted weapons and ECM. The demands of war have created a situation where almost every vehicle is a combat vehicle; a situation that means trucks and light vehicles now need armor and weapons...and combat vehicle manufacturers now need commercial truck expertise. As unit costs escalate, the number of vehicles that can be purchased is commensurately reduced. Re-equipping the ground forces with new equipment at current force levels presents a significant fiscal challenge.

LCS industry output is already declining, and slowly returning back to pre-Iraq levels. Several firms interviewed for this study reported shedding infrastructure and personnel as the work begins to slow. Some anticipate a change in the nature of their work, moving from producing new equipment to servicing and re-building existing post deployment vehicles.

Fiscal decisions by the Administration have forced a reevaluation of the policies to equip the current force. As DoD demand decreases, contraction of the LCS defense industrial base follows. With the cancellation of the FCS MGV, it is uncertain whether or not BAE and GDLS will maintain theirs current size and character, or seek to reduce its physical plant and labor force. Virtually every firm visited as part of the LCS study had some investment in LEAN / 6-Sigma programs to reduce costs. Greater efficiencies through LEAN are intended to stimulate increased demand and provide workforce security, but declining budgets will impose a final limit

on the amount of "LEANing" LCS firms can do without reduction in their labor force. Profit margins reported in the 2009 SEC filings by LCS firms bear out the declining production rates, and declining new sales by even the largest firms in this market sector.[9]

The LCS entry of new firms into the market puts further pressure on the more "traditional" companies' ability to compete. The changing character of land combat vehicles and the budget increase in the LCS market provided an opportunity/motivation for new entrants into LCS supply. Aerospace companies are making inroads as lead systems integrators (LSI)[10] and for electronics integration, while truck firms are seeking partners from armor companies.[11]

The outlook of the industry is uncertain and fragile. Declining DoD budgets, extensive (and evolving) requirements driving expensive vehicles within those budgets, a shift in emphasis from new acquisition to reset and refurbishment contracts, and potential reduction in the DoD organic LCS industry base with a reassessment of the last BRAC findings; a tenuous existence for LCS DIB.

Impact of the Long War on Requirements and Production

The campaigns in Iraq and Afghanistan have had a profound impact on DOD demand for LCS, both in terms of quality (capability) and quantity of vehicles required. In response to this change in LCS demand, accompanied by the requisite budget support, this sector of the US Defense Industry has reorganized and assimilated new players.

Pre-War Trends in the LCS Industry

Prior to the current wars, the Army was engaged in an effort to lighten up its force structure. On the heels of the 1997 QDR the Army reduced the number of active forces heavy tracked combat vehicles by 25 percent. In 1999, the Amy initiated the Stryker program to acquire a light, C-130 transportable, wheeled combat vehicle. Concurrently FCS, initially a C-130 transportable vehicle program, started as the long term LCS replacement for the existing heavy combat forces. Prevailing wisdom was that lighter combat vehicles would be easier to deploy through greatly reduced requirements for support equipment part and parcel of heavy forces, such as fuel tankers, bridging equipment, heavy transporters, armored recovery vehicles, heavy maintenance equipment, etc. The Army's fleet of FCS combat vehicles would be equipped with a network of sensors and communications devices to provide near-total situational awareness. Advocates of this approach believe that speed and situational awareness compensate for the loss of protection provided by a heavy armor. FCS equipped forces could detect, target and defeat the enemy preemptively without the need for heavy armor.

The shift of demand in favor of lighter combat vehicles was not restricted to the US as European nations were replacing heavy tracked combat vehicles with lighter combat vehicles. While EU production of tanks, tracked infantry fighting vehicles, and heavy self-propelled tracked howitzers plummeted, sales of wheeled combat vehicles (Mowag *Piranha*, Patria AMV, and Steyr *Pandur*) and light tracked combat vehicles (Hägglunds CV-90) increased. In 2001 the British Army started their version of the US FCS, the Future Rapid Effects System (FRES). FRES was to replace heavy forces with a network enabled system of lighter wheeled and tracked combat vehicles.

Some of this shift in North American and EU demand was driven by post Cold War defense spending reductions. Lighter combat vehicles were seen as more expeditionary and had

much lower acquisition and operating costs than heavy tracked vehicles. Operations in places like Bosnia, Haiti, Kosovo, and Somalia highlighted the advantages of vehicles small enough to drive on narrow city streets and low weight capacity bridges with sufficient survivability and lethality to deal with potentially surly populations. In other places, however, heavy armored forces remained in favor. Israel continued to build *Merkava* tanks and started to develop a new heavy tracked infantry fighting vehicle based on the very heavy armored hull of the *Merkava*. The requirement for a highly armored IFV was based on experience fighting Hezbollah in southern Lebanon during the 1990s. Similarly, experience garnered fighting Kurdish separatists prompted the Turkish Army to continue investing in heavy combat vehicles. The South Korean Army continued to develop and produce large numbers of heavy combat vehicles to deter its temperamental northern neighbor. In the 1990s the US Marine Corps, not nearly as invested in heavy combat vehicles as the US Army, decided to retain the M1 tank in the active forces and commit to developing a new 40-ton tracked amphibious combat vehicle, the Expeditionary Fighting Vehicle (EFV), while maintaining a sizeable fleet of light armored wheeled vehicles.

An interesting development in the LCS market of the 1990s was increased recognition of the need for highly survivable, tactical wheeled vehicles. Military operations in Bosnia and Kosovo prompted at least two LCS firms in Europe to bring tactical wheeled vehicles with monocoque steel hulls and V-shaped bottoms to the market (early 2000s) to provide protection against small arms fire, artillery shell shrapnel, anti-personnel/tank mines and IEDs. In the US, the Army had begun in the early 1990s to address this requirement in the early 1990s by "up armoring" small quantities of the heavier HMMWV variant, and starting the Armored Security Vehicle (ASV) program to provide military police units a more survivable lethal vehicle suitable for operational environments like Somalia.

Pre-War Organization and Structure of the LCS Industry

Prior to the campaign in Iraq, the LCS combat vehicle industry was dominated by two major firms; United Defense Limited Partnership (UDLP) and GDLS. These two firms remained as a result of LCS industry post-Cold War consolidation driven by governmental direction in the 1990s. They served as the premiere lead system integrators (LSI) for the development and production of combat platforms. GDLS produced the Abrams and Stryker while UDLP produced the Bradley and an assortment of other tracked combat vehicles (M113, M109, M88, M9, M992 and AAV).

Tactical wheeled vehicles were produced by three firms; AM General (HMMWV), Oshkosh Truck (MTVR and Family of Heavy Tactical Vehicles) and Stuart and Stevenson (Family of Medium Tactical Vehicles). A few other firms existed peripheral to the core LCS industry; Boeing IDS (LSI for FCS) and Textron Marine & Land Systems (ASV).

Complementing the commercial defense industry was the Army and Marine Corps organic industrial base consisting of two major combat vehicle depots; Anniston and Red River, and a number of smaller depots (Albany, Barstow, and Letterkenny) and arsenals (Rock Island and Watervliet). Together, this organic industrial base with the commercial LCS contributors mentioned previously provided the implementation of the DoD policy of preserving essential industrial capabilities for future contingencies. Both commercial and organic entities were supported by multiple supply chains, commercial automotive and military unique.

Impact of the War on LCS Product Demand

When the Long War began with campaign in Afghanistan in late 2001, the Army was already well under way towards converting to a lighter force through their programming and budgeting decisions. Experiences in Afghanistan (late 2001-2002) reinforced the shift in demand to lighter LCS products. Light infantry and Special Operation Forces (SOF) supported with air delivered precision munitions had great utility in Afghanistan, in contrast to that of heavy forces that remained garrisoned in the US. To free up funds for the Stryker and FCS, programs reduced included Abrams and Bradley modernizations, and those tied to the "legacy Cold War force" like Future Scout / Cavalry System tracked combat vehicle and Grizzly heavy combat engineer vehicle were canceled.

Over the past 6 years, enemy forces in Afghanistan and Iraq responded to the fall of Kabul and Baghdad by pursuing asymmetric strategies to attack the numerically and technologically superior Coalition forces. The enemy's tactical evolution in the use of small arms and RPGs, then later improvised explosive devices (IED) and explosively formed penetrators (EFP) to inflict casualties and undermine Coalition resolve drove significant change in the LCS vehicles. The effect of 'ever present' threats resulted in two profound changes on the battlefield: the disappearance of both the "front line" and "rear area" of engagement with all troops being vulnerable, and the distinction between combat and tactical support vehicles. These battlefield changes required enhanced survivability, lethality and situational awareness at all echelons. Immediate response was focused on "up-armoring" existing systems. This effort transitioned from "up-armoring" to replacing old systems with factory built systems designed to provide improved survivability and lethality with less degradation to other aspects of performance. As LCS products evolved so did enemy tactics. Changes in enemy tactics triggered demand for further changes in LCS products. By April 2009, threat-driven requirements had changed so dramatically the Pentagon decided to abandon the existing FCS MGVs and start fresh with a new design effort. The Pentagon was also considering whether current and emerging threats have made the current design of the EFV obsolete.

The diminished demand for heavy tracked combat vehicles has been partially reversed as result of the Long War. Pentagon attempts to terminate Abrams and Bradley modernization programs (2002 and 2003) were rejected by Congress. Pentagon leadership has now embraced the need to retain and modernize heavy combat vehicles for the foreseeable future. Like other LCS products, Abram and Bradley vehicles have been upgraded with under belly armor and other enhancements to improve survivability. Modernization plans for M109 self propelled howitzers are in work, a program unlikely to have been a funding priority prior to the war. In Afghanistan, heavy tracked vehicles are prized for their survivability, lethality and ability to traverse terrain impassable to wheeled combat vehicles. Western armies continue to reduce the overall quantities of heavy combat vehicles in their force structure, but most plan to retain and modernize a number of heavy tracked combat vehicles. The Canadian Army has reversed its "all wheeled" plans and will add the *Leopard 2* tank to its inventory while retaining and modernizing its M113-series tracked vehicles. The European armies that deployed to Afghanistan and Iraq confirmed the continuing utility of heavy tracked combat vehicles, using tanks, tracked personnel carriers, M109 self-propelled howitzers and the Panzer Howitzer 2000.

C-130 compatible (20 tons or less) wheeled combat vehicles have been a casualty of the war. Wheeled combat vehicles have grown substantially in terms of weight and size in order to

become more survivable. With add-on armor, belly armor, anti-RPG slat armor, emerging active protection systems, and other items, they weigh in at 25-30 tons with newer models exceeding 30 tons when fully equipped. Afghanistan and Iraq made it clear that wheeled combat vehicles are less mobile than tracked vehicles in many environments —especially when loaded with survivability enhancements. At the same time, wheeled combat vehicles are particularly useful in urban areas where they operate with greater speed and agility than tracked vehicles. Furthermore, many of the wheeled armored vehicles have proven more survivable than light weight, tracked, flat-bottom tracked vehicles like the M113.

Before the Long War, USA and USMC tactical wheeled vehicles were fairly low cost utility vehicles with few survivability and lethality features. They were not universally equipped with communications and other electronic gear; built primarily with commercial automotive technology and designed for on and off-road use in administrative and logistical roles. Tactical wheeled vehicles are now armored to resist small arms, IED blasts and EFP attacks. Most are equipped with communications equipment, many with C2 and mapping software, anti-sniper systems, weapon systems, and electronic counter measures for defeating IEDs. Tactical cargo trucks are now built with armored cabs to carry add-on armor with chassis and drive trains upgraded for the additional weight. Most smaller tactical vehicles are built with monocoque steel hulls and mine resistant bottoms; the HMMWV series is the US land forces exception. As a result of increased survivability, the price of administrative and logistics vehicles has increased sharply. A Soldier on an administrative mission now drives a $150,000 armored heavy HMMWV or a $500,000 - $750,000 MRAP (before the cost of add-on equipment and weapons) instead of a basic $60,000 HMMWV. The next generation of tactical wheeled vehicles will likely be even more expensive. The ECV2 HMMWV and JLTV are expected to cost approximately $250,000 and $500,000 respectively. Cargo trucks prices have increased in a similar fashion.

Impact of Changing Demand on the Organization and Structure of the LCS Industry

The rapid growth in LCS spending during the war prompted the UK firm BAE to purchase United Defense (UD) in York Pennsylvania in March 2005. This acquisition, combined with BAE's takeover of the remaining UK LCS firms earlier in the decade, resulted in BAE Land & Armaments (BAE L&A) becoming a global LCS enterprise operating in six home markets.[12] UD was less than one-third the size of GDLS prior to the war. By 2007, the US portion of BAE L&A revenue surpassed that of GDLS.

Rapidly changing threats and user requirements supported by increased LCS funding provided many business opportunities for firms with good market intelligence, rapid engineering and prototyping capabilities, and access to surge production capacity. This was particularly true early in the war when equipment went through a series of rapid and successive upgrades in response to quickly changing threats. To achieve the necessary speed and agility, many firms created numerous partnerships and joint ventures including partnerships with government depots to support the requirements of surge production. For example, BAE USCS served as a sub to Force Protection (FPI) in 2006 for the production of MRAP type vehicles for the Iraqi Army while GDLS partnered with FPI for MRAP production. The government depots served as metal cutting and ballistic welding subs for OEM firms. Numerous firms sought access to needed technology through international partners. Firms that could not respond with

the required speed and agility had to be content with expanding orders for existing products.[13]

A huge change in the LCS industry has been the merging and partnering of combat and tactical vehicle firms. Prior to the war, combat and tactical vehicles were supplied by distinct sets of firms. This changed when BAE purchased Armored Holdings in 2007 (then the supplier of the Army's light and medium cargo trucks following its takeover of Stewart and Stevenson in 2006). In that same year, AM General and GDLS formed a joint venture, General Tactical Vehicles, to compete for the Joint Light Tactical Vehicle program. The two other current competitors for the JLTV are also partnerships of tactical and combat vehicle firms ensuring that the future JLTV supplier will not be either a pure combat or tactical vehicle supplier. Oshkosh Truck, the heavy tactical truck supplier, remains in the industry as a purely tactical vehicle supplier, but only after unsuccessfully attempting to enter the combat vehicle market by competing for the MRAP and JLTV programs. Undeterred, Oshkosh is currently competing for the MATV program.

High levels of war related spending attracted new entrants to LCS markets. Some of these new entrants were successful and some were not. One new entrant, FPI, entered the LCS market in 2002 offering specialized armored wheeled vehicles for route clearance and Explosive Ordnance Disposal units and later served as an important MRAP supplier. Navistar Defense, a subsidiary of the International Truck and Engine Corporation, succeeded in garnering a large share of the MRAP market and then sold military cargo trucks to Afghanistan, Canada, and Iraq. Navistar is competing for the next FMTV contract and is partnered with BAE USCS as one of the three competing teams for the Joint Light Tactical Vehicle (JLTV) contract. Another important LCS entrant is Lockheed-Martin (LM). Lockheed exited the LCS business after the Cold War but is working hard to re-enter the combat vehicle market. LM has partnered with the Finnish firm Patria for the future Marine Personnel Carrier (MPV) and is partnered with BAE GCS as one of the three competitors for JLTV. The other major aerospace and defense companies seeking to expand their business bases (Boeing, Northrop Grumman, and Raytheon) partnered with existing LCS firms, but were unsuccessful in competing for JLTV.

The LCS industry's agile use of commercial automotive capacity to meet surge production requirements was an interesting feature of the MRAP program. BAE and FPI subcontracted with Demmer Corp., along with GDLS-Canada each subcontracted with the automotive firm Spartan Chassis for the assembly of a large number of MRAPs. The successful use of commercial production facilities during the war raises an interesting industrial base issue. How much organic and defense industry capacity does DoD really need to maintain if commercial capacity can be used to meet surge demand requirements beyond the question of automotive production and assembly capability is that of the test capability? While some of the survivability requirements will continue to require DoD specific testing capability; performance, durability, net centricity and other functions may lend themselves to commercial test capability.

Pentagon acquisition policies have a significant impact on the structure and organization of the LCS industry. As post Cold War spending on LCS products declined sharply during the 1990s, Pentagon buyers modified their acquisition practices in an attempt to preserve LCS development and production capabilities. For example, in an effort to conserve funds, full scale development programs such as EFV necked-down to a single firm much earlier in the development process than had been the case for Cold War era programs. In the case of FCS, the Army deliberately chose to divide the development and production work for the FCS vehicles

on 50-50 basis between UDLP (now BAE USCS) and GDLS to maintain an industrial base of two combat vehicle producers. Likewise, the allocation of production work was often driven by industrial base preservation considerations instead of competition. This methodology allocated portions of limited production work for a given program between depot and OEM facilities based, rather than allocating work to the facility that could perform at the lowest cost. This environment provides little incentive for new firms to enter LCS product markets.

Industrial base preservation has been less of a factor with the rise in LCS investment spending since 2002. In line with recent Pentagon directives favoring competition, the JLTV program is pursuing a traditional competitive acquisition strategy where at least three firms remain in competition until a final down select prior to the start of the production phase. A similar acquisition strategy is envisioned for the future MPC program. Contracts for non-developmental programs such as MRAP and MATV have been awarded on a competitive basis. In this environment it is much easier for new firms to enter the LCS market. With new entrants, the Pentagon is likely to pursue a competitive acquisition strategy for whatever replaces the recently cancelled FCS MGV program. This will provide another opportunity for a major realignment of the industry, but will be tempered by the expected contraction of LCS defense spending on the horizon.

The lessons from this analysis indicate that continuous collaboration between the LCS industrial partners is essential to the industry's ability to anticipate and react with agility in a dynamic environment affected by changes in requirements, budget, and industry structure. Behaviorally, these lessons reveal the need for adopting an effective team approach supported by appropriate policy across all participants in the industry to equip the force during times of war.

Capacity of the Industry

With very few exceptions, overall industry capacity has been sufficient to meet requirements since combat operations began in Iraq and Afghanistan. Production of LCS systems surged from 2002 to 2008 in order to equip the force. This surge production provided the basis of assessments regarding the capability of the LCS industry to handle wartime requirements. Table 1 shows the scale of increased production over the period of the surge.

From the beginning of combat operations in Iraq and Afghanistan until today, the LCS industry experienced a rather gentle and drawn out ramp-up of production. The single exception from the gradual ramp up is armored HMMWV vehicles which experienced a much steeper and prolonged ramp-up. For most of the LCS industry initial production ramped up slowly from 2004 to 2005, sped up from 2006 to 2007 as supplemental funding increased, and peaked in 2008. Production and capacity pressures on the industry would have had different results had the general production ramp-up resembled that of the HMMWV.

During the war, a few industry capacity constraints were noted where the industry could not increase production at a sufficiently high rate to meet the increased demand. Examples include HMMWV capacity from 2003 - 2005 and urgent vehicle survivability modifications required during 2003 - 2006. Industry capacity lagged requirements for fragmentation kits, underbelly kits, and add-on-armor for various vehicle types. MRAP capacity was also constrained during 2007-2008 for a short time while production capacity ramped up. Key factors limiting the rate of increased production included the supply of ballistic grade aluminum and steel, axles, and the availability of qualified ballistic steel welders. The MRAP surge (post 2007) demonstrated that the industry is fully capable of ramping up production and coordinating

specialty metals requirements to meet increased requirements.

Item	2002 Levels (monthly)	2008 Levels (monthly)
Bradley RECAP/Reset	12 / 0	48 / 91
Abrams RECAP/Reset	22 / 0	40 / 24
Armored Security Vehicle (ASV)	3	48
HMMWV Vehicle	20	80
8V92 Engines	77	225
Abrams Transmissions (Allison Recap)	10	25-30
Abrams Transmissions (Anniston Rebuild)	19	48
Anniston Army Depot Direct Labor Man Hours	250,000	583,333

Table 1 - Production Level Comparison 2002-2008

In general, the production capacity for primes as well as the depots has been more than sufficient to meet war related production requirements. BAE (York, PA), GDLS (JSMC at Lima, OH), GDLS Anniston Operations (Anniston, AL), AM General (Mishawaka, IN), and Textron (Slidell, LA) are operating with a single shift (8-10 hours, 5 days a week). In some cases, companies use a limited second shift for parts supply management and vehicle repositioning activities to make production operations more efficient. Most depots are operating at just over 50% capacity and have significant capacity for expansion if required.

Key component producers are working normal shifts and report having plenty of capacity to support LCS production requirements. Military demand for commercial engines and transmissions is small relative to contractor capacity resulting in no capacity issues for satisfaction of increased requirements for commercial products. The situation is different for military unique components. The biggest limiting factor experienced by LCS prime and key component producers is the increased time to receive parts required/ordered as compared to supply chain response during the Cold War era. After the Cold War, demand for military unique items like engines and transmissions declined significantly as the defense department scaled back purchases. Parts suppliers were told to scale back, cut costs, and asked to produce low volumes at a reasonable price when those volumes were required. This commercially unfavorable circumstance reduced the number of willing supply vendors significantly, and increased delivery times and costs. When production requirements increased in support of the war, challenges with downstream supply vendors for military unique parts increased. For example, Bradley supply took in excess of 150 days during most of the ramp up period. The commercial sector has "LEANed" in an effort to minimize cost/maximize profit and removed excess capacity and in some cases, moved it offshore. Additionally, some of the critical supply chain activities are constrained by U.S. Government policies such as ITAR, Specialty Metals Act, and the Buy American Act, covered in later sections.

One noteworthy observation in addition to the raw numbers that deserves mention is the patriotism and innovation of the LCS suppliers and manufacturers. Of course, every firm is in business for profit, but every contact with workers and management revealed something deeper: an underlying desire to do whatever it takes to deliver the best possible equipment to America's

sons and daughters engaged in combat abroad. The same observation can be made of government workers at LCS depots: hardworking and dedicated to turning out quality products for the servicemen and women in the field.

Globalization and Supply Chain Management

Globalization in the LCS Industry. Globalized firms look to acquire services (i.e. research, development and engineering) and goods (i.e. material, parts, components, etc) from whichever source offers them the best deal, regardless of location. These companies have the freedom to move operations to the best business environments; often referred to by economists as "a barge economy." This movement includes both R&D and production. Global firms have the resources to enter and exit national markets and move capacity to where needed in response to changes in demand. These firms are also looking outside their national borders for markets to sell and produce.

Defense industries were once considered national interests and operated solely within their nation's borders. This is no longer the case. Many defense firms now consider themselves international companies with sales to other countries and service centers around the world.[14] For example, BAE Land & Armaments considers itself a global LCS company, with production facilities, sales, and service centers located in multiple countries.[15]

Many defense companies are attracted to doing business in the US as the US defense budget is the largest in the world, and within the past few years a number of US defense industry suppliers have been bought by foreign defense companies.[16] This has strategic implications for US national defense. The US government has less control over these foreign entities than over traditional national defense firms. Since they are not solely US defense companies, their corporate strategies are not focused solely on US national security needs. They develop their business based upon a corporate strategy, and then see how the US defense needs fit into that overall strategy. These companies have a strong incentive to move IR&D outside of US ITAR-type controls, a practice that allows them to maximize IR&D dollars.[17]

Government regulations are not the only factor driving international mergers and acquisitions, this is also occurring without any governmental drivers. The commercial world is accomplishing transnational mergers in order to survive in an industry where demand is not sufficient maintain a large number of suppliers. Firms are consolidating on a global level for the same fundamental economic reasons firms consolidate at the national level. MTU Detroit Diesel transatlantic cooperation for military diesel engines occurred for economic reasons without any government action. Transnational mergers have major implications on the control of technology. The US government cannot control the transfer of technology developed by business or government entities of other countries. Likewise, Germany has tight controls on its technology, so US defense firms that choose to use German technology may not be able to export their products to third party countries without the approval of the German government, similar to US ITAR restrictions. In the case of MTU Detroit Diesel all of the technology development for the company has been moved to their overseas location where it is unaffected by US ITAR restrictions. While this is good business for MTU Detroit Diesel, it has negative impact on the US MTU Detroit Diesel workforce as well as the US engine innovation. Increasingly, US "firewalls" intended to safeguard American technology are having the opposite effect by keeping best practices and ideas out.

This uneven treatment of technology developed internal and external to the US, with

more favorable economic/business treatment of technology developed externally, has the potential of becoming a strategic issue in the future. With a national defense that has long rested on technological superiority, the movement of S&T and innovation offshore could be crippling. With more and more reliance on commercial items and technology, the US will have less technology exclusively available to it and limited control over where that technology is shared. As companies move R&D offshore, the US loses access to the global pool of creative engineering and innovation talent where commercial businesses can take advantage. US Defense firms are restricted to using US based talent pools for military unique items. This issue affects not only military product innovation but also impacts the supply chain, especially with parts obsolescence and replacement. By restricting itself to (US) military unique technologies, the US military could actually fall behind what military capability the commercial world makes available globally.

***Managing Supply Chains in a Globalized Economy*.** There are five strategic issues affecting the supply chain: (1) Military unique components, (2) Parts Obsolescence, (3) Lack of government owned Technical Data Packages, (4) Increased reliance on OEMs as supply chain managers, and (5) the desire of LCS major producers for multi-year contracts.

LCS companies spend an extensive amount of time managing their supply chain. They are constantly looking for alternate sources of supply to mitigate potential obsolescence issues resulting from commercial products changes or vendors going out of business.[18] Some LCS OEMs also provide tooling to their suppliers to ensure long term relationships and reduce risk and cost of delivery. While OEMs prefer to deal with local suppliers due to their shorter delivery times, less transportation costs, and proximity for plant visits, the globalization of the commercial industry is expanding the diameter of their supply circle. One critical area where "local" US environmental regulations have had an effect on parts source selection is in the area of large castings. Environmental regulations have had the effect of making the manufacture of large metal castings economically unviable. As a result, all the firms visited in the US purchased their castings from overseas suppliers, a practice that has potential to disrupt delivery of key vehicle components.

Using commercial parts offers benefits at the cost of having to contend with the risk of commercial obsolescence and limited ability for configuration control. Using commercial parts gives the benefits of lower prices and access to high capacity production in case of surge. DoD does not have to pay the cost of developing the part, but gets the benefits of product improvements driven by commercial demand. However, DoD is at the mercy of the commercial suppliers regarding parts obsolescence and the form that product improvement might take; not always in line with DoD priority. Since the US military needs are usually a small percentage of a commercial supplier's business, DoD is not necessarily consulted (or even notified) when decisions are made to change/upgrade/replace parts, specifically if there is no change intended to the form, fit or function of the overall item. This has strategic impact to our configuration management and repair parts supply processes since the military needs to maintain a standard configuration for as much of the entire 30+ year life cycle of the vehicle as possible. OEMs face this same issue when dealing with their lower tier piece or component part suppliers. Vendors make decisions on what products to build and which ones to shelf based on market demand. To stay competitive many vendors roll out new and innovative products every 6-18 months. Depending upon the particular product market, support for old product lines usually only last about 18-24 months after release of the new product. This disconnect from military support

doctrine will drive the need for continual upgrades to military products and more robust configuration management.

The acquisition policy within the government in recent years not to buy Technical Data Packages (TDPs) for military vehicles including LCS (e.g. ASV and Stryker) and commercial component parts (i.e. Allison commercial transmissions for MRAP) has resulted in the government reliance on the OEM for supply chain management of the repair process.[19] This often results in sole source contracts for support and parts which typically equates to higher cost and less responsiveness than what would result from a competitive process. In some cases, this has forced the government to contract with the OEM for the repair process as well as LCS acquisition and may include OEM field service representatives located in theater. This adds yet another level of cost and complexity to fielding of LCS.

Defense Logistics Agency (DLA) is intended to be the supplier of choice for depots repair parts. Depots, however, increasingly prefer to deal directly with the OEMs for military unique parts. While DLA is a reliable source of many parts, specifically commercially available items, some of DLA's customers were concerned with the ability of DLA to deliver military unique and high technology parts, on time. Deviations on quality were exceptions to the norm, but even small deviations have caused many DLA customers to form public private partnerships directly with the major LCS suppliers to ensure consistency in parts quality and on-time delivery. Depots report that DLA appears to have some difficulty in assessing vendor capability to provide parts that fully conform to all technical requirements beyond easily measurable features.

Another strategic issue affecting the supply chain is the DoD practice of entering into annual contracts instead of multi-year contracts. This practices drives up supply chain costs while conforming to the reality of single year budgets. Longer-term production contracts allow OEMs to enter into agreements with their vendors to produce parts and components at lower costs.[20] With the promise of fixed production schedules, vendors are more willing to enter into pricing agreements with the OEMs and are better positioned and more willing to accommodate any demand surges. Without the ability to enter into longer term agreements, some OEMs buy material at risk in anticipation of government contracts to meet warfighter delivery schedule commitments. This is not a preferred approach for either industry or government. Most of the OEMs visited, when asked to identify strategic issues for the government to investigate, identified the lack of multi-year contracts as one of the most onerous constraints they face.

The Financial Crisis, the "Big 3" Automakers, and the LCS Supply Chain

Industry analysts are worried about the potential effect of a possible collapse of the "US Big Three" automakers. Their concern stems from the recognition that the suppliers common to both the automotive and LCS industries are estimated to be approximately two-third of the automotive supplier base. The cooperation of the Auto Industry with the Army Research and Development (R&D) labs has a rich history of producing capabilities that enhance the safety of US combat personnel. While cooperation between DoD and auto R&D labs has produced improvements made in lightweight vehicles, robotics, and alternative fuels, the relationship is not fundamental to LCS technology acquisition. None of the LCS firms visited noted critical dependencies in necessary R&D. While this mutually beneficial arrangement would be missed if the contribution of the automakers were lost, but would not be crippling to the DoD.

LCS firms visited were queried about their concerns about the health of the auto industry. Some interdependence within the supply chain was acknowledged, but most concern was

centered on challenges faced by their suppliers facing economic issues common in the face of global economic distress. These challenges existed with suppliers whether connected to the automakers or not. LCS supply chain managers saw the impact of an automotive "Big 3" collapse as a contributor to the woes of their supply chain rather than a catastrophic event. Industry analysts believe if there is a bankruptcy by automaker(s), it would most likely be Chapter 11 (restructuring) vs. Chapter 7 (total liquidation). In that case production will continue at a reduced volume and allow survival of automotive suppliers sufficient to meet LCS needs.

The LCS lower tier suppliers considered to be of higher risk were being carefully managed by the LCS industry. Suppliers' viability is measured by their financial strength, operational continuity, technical uniqueness (patent rights/special manufacturing processes), and adherence to quality standards. One firm dedicated a team of logisticians, manufacturing, and design engineers to manage an increasingly complex and volatile supply chain.

Supply chain managers assessed that overall impact on the LCS industry is manageable. Even if the bankruptcy scenario will affect the auto industry, the consequential impact will be translating into costs increases with regard to the cost of replacement parts, while flow of the parts will remain steady. As such, the overall risk to national security, based on the impact of distressed suppliers on the LCS community is considered "low."

Labor Management Relations

The LCS industry workforce declined during the 1990s, but peaked again in 2008 because of war-related requirements. However, reductions in LCS workforce due to reduction in DoD procurement funding, changes in procurement strategy, and the global economic crisis are on the horizon. Recent attention to acquisition challenges has reemphasized the importance of competition. As a result, seeking the competitive advantage in government acquisition, competition is motivating firms to use labor more efficiently. For example, firms and unions now work together more collaboratively to remain competitive, realizing if they do not work will go to other firms, and both labor and management will lose. Many LCS firms are invested in LEAN initiatives and other innovative ways to improve processes and cut costs while government operated entities are expanding into enterprise roles and seeking relationships such as labor sharing and partnering to remain competitive in the market. One concern with the "rush to LEAN" for cost competitiveness is the risk of sacrificing agility. During this study, only one firm, GDLS, noted the competing capabilities and accommodated them in business planning.[21] However, GOCO locations appear to be less aggressive in pursuing LEAN initiatives simply because there are no clear incentives to encourage better business practices. It should be noted that LEAN is easier to accomplish in a rising market where increased work absorbs workers that are "LEANed" out, it will be difficult to avoid workforce reductions with declining markets.

LCS production shops are primarily union shops. Unions and defense firm management report good relationships where strikes are rare and no labor disruptions have occurred in the last 20 years. Management and labor are working together out of learned necessity and the trend is for management to share business information with the unions. In most shops visited union meetings have transformed into meetings with business agendas and unions are sufficiently informed to self police their workers. Metrics that tie performance to pay are the standard.

Touch labor typically accounts for 10% of production costs and is a focus of the depot community where touch labor is prized. Ballistic steel welders have a skill set that remains at high demand and make up the majority of the specialized skills LCS workforce.[22] To overcome

a shortage of welders, some firms incorporated welding certificate program to train and certify their own welders. Both US firms (e.g. BAE, Textron) and European firms (e.g. Renk, KMW) have their own training programs. Most (commercial) LCS production sites are highly automated while some operations remain fairly labor intensive. For depots, the workload determines the workforce, touch labor is the focus, and the DoD 50/50 rule guarantees some work.[23] Surge hiring has resulted in a young workforce, with a large proportion of workers with less than five years of experience.[24]

Along with DoD demand, global competition, technological changes, and demographic shifts affect the character of the labor force required by the LCS industry. Future work must be forecast in out years to ensure proper work force, a daunting task in a market that is characterized by changing requirements and an increased need for responsive agility. Surge labor peaked in 2008 but now mirrors the downturn in DoD demand for LCS.[25] LCS manufacturers are concerned that potentially reduced future requirements will force a commensurate reduction in their workforce. To posture for an uncertain future, firms and depots are managing labor requirements with tiered employment status. Preparation for this inevitable reduction will be accomplished, if accomplished at all, individually by LCS entity, reflective of its singular planning capability. Government LCS entities incorporated practices to protect permanent workforce (hiring temporary employees, overhires, overtime, outsourcing, and partnering) to posture for future reductions. They are collaborating in the form of joint ventures, private-public partnering, and labor sharing to improve quality, efficiency, and competitiveness. They are also using some innovative intern and co-op programs to recruit quality employees and feed a talent pool into their workforce.

Transmissions

There are only a few providers of heavy-duty transmissions in the market for land combat systems. Allison Transmission is the dominate company, and has captured 80% of the world market for commercial heavy-duty automatic transmissions, and 90% of the U.S. market. During the Cold War, providing transmissions for the military accounted for about half of Allison's revenue. However, military contracts are only about 7% of Allison's current business. With only a few exceptions,[26] Allison provides all of the "military unique" transmissions used in the United States, as well as most of the commercial transmissions used in all other vehicles.

Because there are so few providers of military-unique transmissions, market competition does not determine price because each military-unique transmission has only one producer and one buyer. Instead, producers have considerable leverage in negotiating with the government. Because volumes are so low the government is paying significantly more for transmissions than for similar commercial transmissions. What the government gets in return is very good quality transmissions, and excellent configuration control.[27] The price of the thousands of commercial transmissions used in military vehicles is determined by the commercial market.[28] Again, the military gets very high quality transmissions, but now suffers from a lack of configuration control. The producers upgrade their commercial transmissions with every improvement in technology to remain competitive in the marketplace, and the military supply chain managers to have to adjust to commercially driven configuration changes.

Because Allison is the only producer of the M1 Abrams tank transmission, and the DoD is unwilling to give Allison a multi-year contract for the M1 transmission, the government has had to reduce the investment cost and risk for Allison by providing most of the tooling in Allison Plant 14 (Indianapolis, Indiana), the primary place where these transmissions are built and

maintained.[29] The M1 Abrams has been out of the production for many years, and Allison is rebuilding about 25-30 transmissions per month for the U.S., plus two new transmissions a month for the Egyptian Army. Because of low production rates, Plant 14 has significant excess capacity beyond these requirements.

The Engine Market

Commercial engine consumers must have engines that comply with federal emissions laws, but the military customer does not have to buy emission compliant engines since they have a National Security Exemption.[30] The military has a long history of using commercial engines for their wheeled vehicles. Use of commercial engines offers many benefits - low prices, access to surge production capacity, up-to-date technology, and a large life cycle support network. New emission standards, however, are causing military consumers to reconsider whether they should continue to buy commercial engines. Up until recently the military was reasonably satisfied buying emission compliant commercial engines. The latest emissions standards, however, have caused military and commercial requirements to diverge. Engines compliant to the latest emission standards are larger, less durable, and have a greater heat signature than engines built to previous emission standards. More importantly, new commercial engines will not operate on JP-8 or other high sulfur fuels; they must run on ultra-low sulfur fuels.

Currently, combat vehicles are exempt from emission standards. New emissions standards for military trucks manufactured in 2004 or later mandate that emissions be cut to less than half of the prevailing standard. Those vehicles that do not qualify as combat vehicles (i.e., trucks without armor) will need to meet these reduced emissions standards. If the military desires to use commercially available engines, they will have to use commercial engines with the reduced emission standards. This creates a dilemma for the DoD. The dilemma is that the emission standards for commercial customers (and those leveraging commercial engine technology and production volumes) are getting stricter and will force all on-road and off-road truck users to use ultra-low sulfur burning engines, which in turn challenges the "single fuel on the battlefield" doctrine. The DoD has to make a choice; either rely on increasingly more ancient technology and continued use of the old commercial engines or change their doctrine and move to use the new emission compliant commercial ultra-low sulfur diesel engines.

Science, Technology, Research, and Development of LCS Systems

Science and Technology.[31] The Land Combat Systems (LCS) Industry relies on government labs, universities, and commercial firms to provide advances in technology. Prime LCS developers are users and integrators of technology development rather than initiators. Technology development is not a core competence of LCS prime contractors.

A consequence of the Long War is that the LCS technology development portfolio is heavily invested in near-term objectives. Survivability has been the key requirement commensurate with the threat of Improvised Explosive Devices (IEDs), Explosively Formed Penetrators (EFPs) and Rocket Propelled Grenades (RPGs). The transition to lightweight structures, e.g., composites, electro-magnetic and ceramic armor has focused on attainment of survivability without a disabling weight penalty affecting other requirements.

With a focus on the near term and fewer funds allocated for technology development, there are few long-term technology development advances being researched. Long-term technology development objectives have been underfunded to meet the requirements of the wars

in Iraq and Afghanistan. While the nation is at war, DoD is having to allocate resources and make trade-offs that may affect long-term technology development. The fact that very little long-term technology development is underway may have lasting negative consequences for the future of land combat operations. One area where longer term research is currently underway at Tank Automotive Research, Development, and Engineering Center (TARDEC) is modification of ultra low sulfur diesel burning commercial engines to run on JP-8 fuel. If this effort is successful DoD decision makers will have much more flexibility in their resolution of engine emission/fuel strategy issues.

Another consequence of short term focus on short term war related requirements that should be of concern is the tendency for haste to transition technology before it is ready. An example of such a technology hastened to production that might cause what the government tends to call "technological surprise" is Friction Stir Welding. This promising technology, under consideration for integration into several of the land combat/tactical vehicle systems and associated facilities, has yet to be proven for several of the alloys contemplated for near term production.[32] Overall decreased DoD budgets will only aggravate this concern with "rush to implementation."

Research and Development.[33] The campaigns in Iraq and Afghanistan have changed the budget environment and that in turn has changed the type of acquisition strategy DoD can afford to use for product development. The structure, conduct, and performance of LCS product development were vastly different prior to the start of the Iraq campaign. There was significantly less money for product development, which meant the DoD could not afford to have multiple firms compete during the phases of the product development process. Because of these funding limitations, development programs had to neck-down to a single firm early in the development cycle. In the absence of competition, controlling cost is difficult and firms are not necessarily motivated to deliver their best performance. History shows that as the budget environment changes, acquisition strategies will change, and this will result in different Land Combat System industry outcomes/performance in the area of product development. Two examples of programs that encountered difficulty caused by DoD budgetary constraints were the EFV and FCS MGV. The EFV development problems were caused by 1990s budget constraints, where inadequate funding caused the program to neck-down to a single firm before the first prototype was built. Instead, the EFV program adopted the less expensive "reliability growth" design method, which meant the program would accept some design risks.[34]

FCS MGV development problems stemmed from industrial base preservation decisions that were related to budget constraints. There was a perceived need to preserve two combat vehicle design houses to decrease risk of one of two firms losing its product development skills. The Army deliberately chose to divide MGV development work on a 50-50 basis between United Defense (now BAE) and GDLS in an attempt to maintain the existence of these two combat vehicle suppliers. This decision removed the motivation for "best effort" as the level of work to be awarded to each participant was pre-ordained, and independent of competitive effort.

In this type of competitive acquisition environment, it is much easier for new firms to enter the LCS market. With less reason to worry about industrial base preservation, the Pentagon is likely to pursue a competitive acquisition strategy for the redesign of the recently canceled FCS MGV program. When this type of competitive environment exists in complex system development there is opportunity for expansion and realignment within the LCS

industry. However, there is a limit to the expectation for LCS DIB expansion. The downturn of the global economy is already influencing the DoD budget. If funding deteriorates for modernization programs, a return to high-risk acquisition strategies driven by tight budgets and industrial base preservation concerns may be the result. Ultimately, the DoD acquisition strategies in 2015 may well resemble those of the 1990s, and yet another cycle of DoD acquisition reform will most likely follow.

POLICY RECOMMENDATIONS

Through intensive study of both the government and private perspectives of the LCS industry, the LCS seminar developed some mid-term policy recommendations for consideration. These recommendations are grouped according to their applicability by sector of the industry.

- A DoD policy is needed to allow facility management leaders at government-owned facilities authority to either charge customers for capital expenditures like tooling, or there should be a budget line for capital maintenance and upgrade; a balance between competitiveness and protection.
- For JSMC to remain a viable national resource, the facility should be managed as an enterprise rather than merely as "an M1 tank factory." A business case analysis should be conducted to determine the most efficient business model for the enterprise. The analysis should include alternatives such as transferring management to TACOM, divesting the facility to GDLS, or creation of a governing board consisting of relevant stakeholders.
- A business case analysis should be completed on Plant 14 at the Allison Transmissions complex to determine the most cost-effective approach of maintaining legacy transmissions. The analysis should consider closure, re-location, recapitalization in-place, or retention of the status quo. Give projections for declining markets, the study should consider opportunities for a commercial partnership between Allison and Renk for the development and production of military-unique transmissions.
- The BRAC 2005 round determined there was excess capacity in the Army depot system. In light of the expected ramp down in requirements, and the fact that the depots were all operating at less than full capacity during the current conflict, the BRAC 2005 recommendations should be re-visited, and, if still applicable, implemented.

Operating the Industrial Base in a Global Economy

- The Administration should propose legislation relaxing or eliminating regulations that place efficient supply chain management at risk like "Buy American" provisions and the Specialty Metals Act.
- Depots and contractors should be able to access OEM parts directly without having to go through the Defense Logistics Agency (DLA) supply system, based on a business case on an individual purchase basis.

Engines & Transmissions

- DoD should establish a joint logistics coordination board to evaluate energy portfolios against the energy disconnects in order to identify and optimize solutions across the Services, broader department objectives, and US government strategic energy objectives.

- DoD should move to use of commercial engines in their vehicles, and in doing so will have to alter the "single fuel doctrine" in order to incorporate commercial fuels like low-sulfur diesel, commercial gasoline, and JP-8 derivatives (like synthetics). Such a policy would ensure lasting access to the cutting edge powerplant technology.

Acquisition Policy

- The DoD should increase the use of multi-year contracts to ensure funding stability for LCS programs, and incentivize manufacturers to re-capitalize their facilities to preserve the defense industrial base.
- DoD policy should require purchase of the technical data packages (TDP) from LCS major producers, deviations by exception. Experience shows that the future cost of not purchasing the TDP far exceeds the present cost of buying during the competitive phase of acquisition. Owning the TDP would place the DoD in a more advantageous position for follow on repair work, as well as developing new products. TDP ownership will facilitate maintaining a base industrial capability at lowest cost to the DoD.
- As LCS become more complex, technologically advanced, and expensive, implementing a sensible Unit ID policy for critical components becomes advisable. UID will enable more accurate projections of the lifespan and survivability for those components.

Science, Technology, Research, and Development

- DoD leadership and Congress should establish structures and policies that enable US LCS firms the ability to leverage intellectual capital globally, accessing global engineering capability where possible to ensure the best technology for US forces.

ENDNOTES

[1] The U.S. military is the most important market for this industry. Firms in this market rely on purchases from the U.S. government in order to keep themselves economically viable. In 2006, 3.8% of the Army budget was planned for investment in weapons and tracked vehicles. Nearly 15% of the 2007 Army budget authority was allocated for the upgrade of Tracked Combat Vehicles. Most of the balance of this industry's product goes to overseas military procurements and is reliant on the ability of the U.S. military to enter into cooperative agreements with the procuring international entities. *("Tank and Armored Vehicle Manufacturing in the U.S." IBISWorld Industry Report, http://www.ibisworld.com/industry/default.aspx?indid=857 (accessed 02/28, 2009).)*

[2] "Tank and Armored Vehicle Manufacturing in the U.S." IBISWorld Industry Report, http://www.ibisworld.com/industry/default.aspx?indid=857 (accessed 02/28, 2009).

[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Government Owned, Contractor Operated

[7] Defense Update. *Defense Update Online*. http://defense-update.com/newscast/1206/news/221206_Cougar.htm. Accessed 22 May 09.

[8] Scully, Megan. "Army Chief To Shift New Vehicle Program Into High Gear". *NextGov.com*. May 12, 2009. Accessed 22 May 2009.

[9] Compilation of 2009 annual SEC 10-K filings for BAE, GDLS, and discussions with executives from firms visited during domestic travel March 2009.

[10] DoD Public Affairs (Release No. 109-02, March 07, 2002). "DARPA, ARMY Announce Future Combat Systems Lead System Integrator". *DefenseLink*. http://www.defenselink.mil/releases/release.aspx?releaseid=3261. Accessed 22 May 2009.

[11] "More MRAPs: Navistar's MaxxPro Maintains the Pole Position". *Defense Industry Daily* (online edition). http://www.defenseindustrydaily.com/more-mraps-1200-maxxpro-mpvs-from-navistar-03344/. 5 May 2009. Accessed 22 May 2009.

[12] Australia, South Africa, Saudi Arabia, Sweden, Turkey, UK, and US

[13] Pre-Iraq, O'Gara Hess (later bought by Armor Holdings) and Ceradyne were the two major firms in specializing in the armoring business. BAE L&A and GDLS had substantial in-house armoring capability. DoD Demand during the war drove growth in the number of domestic and foreign firms supplying armoring materials and systems level armoring packages. Armoring packages have become a key element of product differentiation in the industry. Industry responded with partnerships and some vertical integration of vehicle and armoring activities. The Israeli armoring firm Plasan became an important supplier to Oshkosh Truck and Navistar Defense, traditionally sellers of unarmored vehicles. In 2006, Armor Holdings (armor manufacturer) acquired Stewart and Stevenson, the manufacturer of the Army's light and medium cargo trucks. Armor Holdings held data rights to the original HMMWV armoring package and served for several years as the monopoly supplier of HMMWV armor until AM

General developed a competing armor package. AM General eventually developed in-house capability to design and manufacture armored HMMWVs and succeeded in capturing this important market.

[14] General Dynamics Land Systems has bought into the European Market and is now a contender on the British Future Rapid Effects System (FRES) contract for combat vehicles using a Swedish MOWAG design.

[15] BAE Land & Armaments has home markets in: UK, US, Saudi Arabia, South Africa, Sweden, and Australia, with recent partnerships established in India. While BAE is a UK company, BAE Systems is a US Subsidiary with a US Board of Directors. In January 2009 BAE Systems Land & Armaments restructured into four business areas: U.S. Combat Systems focusing on the U.S. Department of Defense, specifically ITAR-controlled U.S. products and FMS sales; Global Combat Systems focusing on global customers; Global Tactical Systems focusing on medium/heavy vehicles and tactical trucks worldwide; Security & Survivability focusing on security and support services globally.

[16] Examples include BAE establishment of BAE Systems and purchase of United Defense, Finmeccanica purchase of DRS Technologies, Daimler's purchase of Detroit Diesel, and MTU's purchase of Detroit Diesel's off road and military engine market.

[17] Both Daimler and MTU moved all engineering and R&D efforts from Detroit Diesel in Michigan to Germany. While this avoids the US ITAR regulations, Germany has strict control over its technology release.

[18] This is even more critical due to the recent economic downturn and reduced orders for parts in the commercial sector. Supply chain managers are developing contingency plans and looking at the health of their vendor base, providing tooling and financial assistance, qualifying alternate sources, and ensuring sufficient stock is on hand to meet future production needs. Supply chain managers also need to be aware of patents and unique manufacturing processes that are controlled by their vendors which could be serious barriers to entry for alternate sources.

[19] Programs using OEM as supply chain manager for repair process include: ASV Reset, Stryker, Bradley Reset, Abrams Reset, HMMWV Reset, M1 Abrams Turbine Engine Rebuild, M1 Abrams Transmission Rebuild.

[20] Multi year contracts with confirmed procurements for fixed quantities over multiple years allow OEMs and vendors to forecast workload and buy material and components in bulk, realizing economic order quantity savings over small annual procurements quantities.

[21] Need this- private ownership, long range strategy, labor in business meetings, lean/union agreement.

[22] Assembly workers wages range from $12 - $17 per hour; welders start at $25 per hour. Wages are slightly higher than other firms in the area; locals seeks employment at defense companies

[23] 10 USC 2466.

[24] Anniston Army Depot's average workforce age is 43 years

[25] Depot workload peaked in FY08 at 6.9 million work hours; FY09. 5.7 million and FY10 & FY11 expected to be 5.1 million each year

[26] While John Deere and Caterpillar make heavy-duty tractor transmissions, they have not seriously attempted to compete for a share of the military combat vehicle market. Twin Disc makes transmissions for the M-88 Armored Recovery Vehicle; L3 provides the transmissions for the M2 Bradley, Multiple Launch Rocket System (MLRS), and foreign tracked military vehicles. L3 has competed in recent years for additional tracked vehicle contracts.

[27] This is because the producers are not willing to invest their money into improvements or changes, so the configurations are stable, and this enhances military supportability. On the other hand, the military transmissions do not get the benefit industry improvements—unless the military pays for an Engineering Change Proposal (ECP).

[28] Although there are a number of companies that could compete to provide commercial transmissions for wheeled combat vehicles, Allison is providing about 90%. Some AM General HMMWVs do not use Allison transmissions, but their new ECV2 models do. Allison has had to compete for the tracked vehicle transmission market with General Dynamics (now L3 Propulsion), Twin Disc, and Renk. Caterpillar (and perhaps John Deere) has shown interest in the market, as well.

[29] DLA has awarded breakout contracts to commercial companies to build spare parts and rebuild kits for Allison M1 Tank transmissions. However, those parts do not exhibit the exacting standards and quality of the original Allison parts. Also, Anniston Army Depot has not exhibited the same quality work when using breakout parts to rebuild these transmissions. The result is that, although new Allison transmission last for 30,000 miles, and Allison rebuilds last 21,000 miles, Anniston rebuilds only run for 7,000 miles. Even though the Allison rebuilds cost significantly more than Anniston rebuilds, considering the life of the rebuilds and transmission down-times, Allison rebuilds may be a bargain.

[30] 40 CFR 1060.605

[31] Science and technology equates to technology development.

[32] Office of Naval Research, Science and Technology Office of Transition Success Stories. "Friction Stir Welding of Aluminum Armor". March 2002. Available online: http://www.onr.navy.mil/sci_tech/3t/mantech/docs/success_stories/ground_vehicles/groundvehicles_AAAVFrictionStirWelding_120805.pdf.

[33] Research and development equates to product development.

[34] EFV had to reduce reliability to AAVs original level.