

**Spring 2007
Industry Study**

Final Report
Land Combat Systems Industry



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Fort McNair, Washington, D.C. 20319-5062

Land Combat Systems 2007

ABSTRACT: The seminar surveyed the state of the U.S. Land Combat System industry. The study found that the current LCS industry has responded well to the demands of wartime production. Funding fluctuations, Berry Amendment requirements, and long lead times contributed to delays in some procurements, leading the study to make recommendations for improvements to wartime acquisition processes. In the near future, the demand for tactical wheeled vehicles will increase because the Iraq conflict has led to a new emphasis on survivability. Commanders want their trucks armored, networked, and carrying weapons. Current plans also call for an increase in the demand for combat vehicles. Refurbishment and modernization will continue on current systems, and new systems are in development now. A combination of budget problems make it unlikely, however, that DoD will be able to afford to fund all its programs while retaining its current industrial base. DoD may have to make hard decisions about whether to consolidate government depots, and the drop-off in funding may cause more mergers and acquisitions in industry. The study concludes with recommendations for how the United States should manage the industrial base during the inevitable funding drop-off if it wants to be ready for the next war.

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PLACES VISITED

Domestic

Anniston Army Depot, Anniston, AL
General Dynamics Land Systems Anniston Operations, Anniston, AL
Aberdeen Test Center, Aberdeen, MD
General Dynamics Robotics Systems, Westminster, MD
Letterkenny Army Depot, Chambersburg, PA
BAE Systems Ground Systems Division, York, PA
Program Manager, Expeditionary Fighting Vehicle, Woodbridge, VA
Program Manager, Joint Light Tactical Vehicle, Woodbridge, VA
Program Manager, Stryker, Warren, MI
Deputy Program Manager, Future Combat Systems, Warren, MI
Program Executive Office for Combat Support and Combat Service Support, Warren, MI
MTU Detroit Diesel, West Detroit, MI
General Dynamics Land Systems, Sterling Heights, MI
Joint Systems Manufacturing Center, Lima, OH
Allison Transmissions, Indianapolis, IN
AM General, South Bend, IN

International

Steyr-Daimler-Puch Spezialfahrzeug, Vienna, Austria
MAN, Munich, Germany
Krauss-Maffei Wegman, Munich, Germany
BAE Systems Hägglunds, Ornskoldsvik, Sweden
BAE Systems Bofors, Karlskoga, Sweden
Saab-Bofors Dynamics, Karlskoga, Sweden
Stockholm International Peace Research Institute, Stockholm, Sweden
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Land Combat Systems Industry

Land combat systems provide the ground-based power and mobility for the United States armed forces, enabling them to execute their doctrine of maneuver warfare. During Operation IRAQI FREEDOM (OIF) and Operation ENDURING FREEDOM (OEF), operators of Land Combat Systems (LCS) have carried an enormous load, bearing the brunt of the assaults by a determined enemy. The industry producing and supporting these systems is also important, a market worth \$38 billion in 2006¹. The structure, conduct, and performance of this industry therefore warrant careful study.

In general the LCS industry produces wheeled and tracked armored combat vehicles, tactical wheeled vehicles, mobility and counter mobility systems, soldier systems, and network systems. Manufacturers of these systems can be found worldwide. This study focused on the domestic producers of wheeled and tracked combat vehicles (WTCV) and light tactical vehicles (LTV). This report examines the European LCS industry but focuses on what that market can teach the United States.

This study begins by outlining the nature of the demand for LCS as a public good, exploring the monopsonist power of the Department of Defense (DoD) and how the intricacies of democratic government temper that power. The paper then explores the history of the industry, tracing its transformation in the twentieth century from a series of government-owned armories to a mixture of private corporations and government depots. The central section of this report is the review of the current state of the industry, examining how companies have responded to the increase in demand during the current war. The study continues by comparing and contrasting the European LCS market with the U.S. market. The next step is to forecast the future demand for WTCVs and LTVs, and how these vehicles are likely to change. The report follows these sections with an assessment of the outlook for the industry in light of the inevitable decrease in DoD spending when combat operations subside. The study concludes with recommendations for ensuring the LCS industry is well-positioned to survive the coming drawdown and support the next war.

The report finds that the consolidation of DoD corporate suppliers in the 1990s resulted in only two major providers of WTCVs, but they were sufficiently diversified to support the current surge in production. Producers of LTVs are more numerous, and have also responded well to increased wartime demand. The supporting network of subassembly manufacturers, vendors, depots, and armories have all demonstrated generally good capacity and responsiveness, though there have been some materiel supply shortages. The report also concludes that further consolidation in the LTV market will probably occur, but the WTCV market should not become any less diverse. The study provides recommendations for government policy to ensure the LCS industry remains healthy. If the United States wants land combat systems and the industry that supports them to power the next war, DoD will need to manage the coming drawdown carefully.

Land Combat Systems Demand

In order to understand the structure, conduct, and performance of the U.S. LCS industry it is essential to understand the determinants of the demand for LCS.

This industry is a part of national defense, a “public good.” One reason public goods are distinguishable from commercial or private goods is because they are non-excludable². “Non-excludable” means that people who don’t directly contribute to the resourcing of a good can not

be excluded from its benefit. As a result, individual citizens do not ordinarily have a strong incentive to purchase national security on their own.

The U.S. Government bases its demand for LCS on a wide variety of factors, including cost, fiscal priorities, perceived threats, technology evolution, social perceptions, and the need to maintain an LCS industrial base for the future.

The government serves as a monopsony because it is the only domestic procurer of LCS. Therefore, the government has the bargaining power and can greatly influence the suppliers within the sector. For example, the quantities, over what timeframe, from whom it purchases, and the type of procurement all yield leverage to buyer. It is reasonable to believe that like other public goods, the law of demand applies to government consumption of LCS—the quantity of LCS consumed varies inversely with price. If the price of LCS were to increase, it is likely the government, at the margin, will shift from LCS to substitute inputs used to provide national defense, i.e. systems related to air and sea power. Likewise, if the price of complement inputs such as the military labor used to operate and maintain LCS were to rise, the government would, at the margin, likely consume less LCS and more of other inputs used to produce national defense.

In the last century, the demand for LCS relative to other National Defense inputs has generally declined as a result of: (1) the substitution (at the margin) of relatively less costly tactical and strategic forms of air and sea power for land power and (2) a steady increase in the pecuniary and non-pecuniary military labor costs associated with operating and maintaining LCS—a national defense input that is relatively more labor intensive than air and sea power systems. Because of the steady rise in labor costs LCS is steadily becoming more capital intensive as capital is substituted for increasingly expensive military labor.

If a nation chooses to maintain an LCS industrial base it receives the security benefits of being able to produce LCS independent of foreign meddling. However, the nation must be prepared to pay potentially higher prices. If a nation's peacetime demand for LCS is large relative to the optimal LCS capacity, then it may be possible for a nation to buy LCS purely on the basis of best value competition and still maintain an industrial base that can be expanded to meet wartime needs. If peacetime demand is small relative to the optimal LCS industry capacity, then the policy objective of maintaining an industrial base for wartime requirements will generally conflict with the broad use of competition as a means for awarding LCS development and production contracts. For more than one firm (publicly or privately owned) to exist in the market, the government, to some extent, must award work on the basis of other factors in addition to best value. In essence the government must treat the industry as a public utility and accept the higher peacetime costs associated with maintaining excess capacity needed for wartime production.

Understanding this trade-off of accepting higher cost in return for maintaining the capability to meet contingent needs is extremely important in evaluating the structure, conduct, and performance of the U.S. LCS industry. The U.S. government does not simply buy LCS products. The U.S. government buys products and, through the price of the products, funds an industrial base that maintains engineering and production capacity that is excess to peacetime requirements but necessary for wartime. Therefore one cannot simply evaluate the LCS industry on the basis of the instant cost of LCS products, the degree of competition in the market, or the efficiency of its development centers and production facilities in peacetime. One must evaluate the industry in terms of the how well and how efficiently the industry is satisfying its twin missions: (1) developing and producing state-of-the-art systems to satisfy current demand, and

(2) maintaining the engineering and production capability to develop and manufacture a full spectrum of state-of-the-art LCS products that may be needed in the future.

Another unique aspect of LCS demand is that governments make their LCS purchasing decisions somewhat differently than consumers and firms. Consumers maximize their well-being (or utility) whereas firms maximize the return to their shareholders. The economic objectives of governments on the other hand are not well-defined. The U.S. government's decision making process is based on the concept of shared powers between three branches of the federal government enforced by a system of checks and balances. Decisions on how LCS is purchased and how much is bought are subject to broad compromise among competing interest groups who often have conflicting objectives. LCS purchasing decisions may reflect considerations other than what is the best price-quality course of action.

Lobbying further complicates the government decision making process. LCS firms have the opportunity to significantly influence government LCS decisions. In markets for private goods and services, firms can use advertising and other types of marketing to persuade consumers to buy their products. Defense firms can do the same and much more in the LCS markets. Unlike markets for private goods and services, decisions on the consumption of a public good like LCS is made by elected and unelected representatives of the ultimate consumers—the citizens. Such representatives in the executive and legislative branches of the federal government may be lobbied to make decisions—in exchange for various forms of political support—that may not necessarily be in the best interests of the ultimate consumer (e.g., keep an unneeded government owned enterprise in business or establish procurement practices that limit competition or provide economic benefits to certain parties). Thus, the economic well being of LCS firms (or other stakeholders like labor unions) is dependent not just upon the firm's ability to compete on the basis of price and quality but also its “political efficiency”—the ability to influence the public decision making process to the advantage of the firm. The ability of LCS firms to participate in the “consumer's” decision making process is a somewhat unique and important aspect of the LCS industry.

So in conclusion, understanding the complex dynamics that influence demand for LCS is essential to comprehending this industry. Elected officials and policy makers routinely grapple with maintaining a force in ready comprised solely of public goods. Additionally, the need to sustain an effective LCS industrial base, a complement good to the weapons themselves, affects how much the government seeks substitutes like air or sea power. The government, as a monopsony, regulates the demand while taking into consideration many external influences. These influences are compounded by competing interests and other political agendas and concerns. Balancing cost/benefit analysis and defining the need, fiscal constraints, and emerging threats all drive the need for LCS to maintain the nation's security.

History of the Land Combat Systems Industry

As the LCS industry faced the prospect of a surge in demand following the events of 9/11 and the ensuing military operations in Afghanistan and Iraq, it did so with a character defined in the sixty year historical period from 1941 to 2001. During this seminal period, major and minor military conflicts, as well as the end of the Cold War, profoundly transformed the LCS landscape. This transformation is evidenced in several distinct trends: the shift of production responsibility from arsenals to industry; fundamental changes in the production and the budgetary environments leading to industry contraction; the evolution of design responsibility

from the military to industry and the attendant infusion of technology into LCS; the transition from a vast network of depots to depot partnering with industry and the reduction of depots to a few specialized ones; and the introduction of protectionist legislation and regulation that would progressively shape the LCS supply chain. The LCS industry that confronted the reality of the Long War therefore was defined by few suppliers, diminished overseas sales, and increased reliance on depot partnering.

The post-9/11 challenges of the LCS industry did not rival the anemic condition of the LCS industry before World War II. Ground forces were chronically neglected in the inter-war years. From 1919 to 1935, the Army procured only 33 tanks, the vast majority of which were manufactured by the Army itself at the Rock Island Arsenal³. However, World War II changed the market fundamentally. President Roosevelt declared a national emergency and ordered cessation of all automobile production by 1942⁴. The leading manufacturers of that industry—Chrysler, Ford, General Motors and Cadillac—were converted into wartime production, initially in support of U.S. allies, that created a longstanding dependence on foreign buyers that would not diminish until the last decade when off-sets and foreign protectionism became dominant themes. Other heavy industries, such as locomotive and food machinery companies, also were converted to production of land combat vehicles at government direction. The similarity of components and production processes between legacy commercial products and military vehicles made for a seamless transition of these industries into LCS production⁵. Moreover, the entrance of industrial firms into the LCS market effectively ended the arsenal system's role in large scale LCS vehicle manufacturing; the role of arsenals after World War II became increasingly specialized and supporting in nature.

This surge of entrants into the LCS market was not sustained over the period from 1941 to 2001 due to changes in production rates and quantities. As mentioned previously, the new entrants into the LCS market during World War II were commercial entities with resident competency in both engineering and manufacturing. As a Chrysler executive explained in 1948, industry valued volume, sustained output, efficiency, and cost control above all⁶. However, the production history of systems during the period shows progressive declines in production quantities and dramatic increases in length of production. World War II was a period of high production volume and short production runs. During the Korean War, aggregate production quantity was still significant, although expectedly less than World War II, and production runs increased in duration, but only slightly. However, during and since the Vietnam era, production quantities were relatively low (around 8,000 for a given model) and lengths of production rose sharply to more than a decade. The culmination of this trend was arguably seen in the M-1 Abrams Main Battle Tank and the M-2 Bradley Infantry Fighting Vehicle. These vehicles, produced during the Reagan era military buildup, actually were designed in the early 1970s. Peak production of both vehicles occurred in 1986.⁷ Naturally, then, in these market conditions, there was an increasing government tendency to rely on retrofitting existing systems in lieu of producing new, more capable models or variants. This new strategy placed greater emphasis on developing technology and technology insertion than on procurement of new systems.⁸ In the LCS industry, upgrades were used to maintain technological superiority while ensuring the LCS industrial base could be sustained for future development and production. This new approach to maintaining the industrial base was critical for the survival of the LCS industry. The production environment by 2001, therefore, was radically different than what new LCS entrants faced in 1941 and ran counter to expectations of how a manufacturing firm should optimally operate.

Because of this, over the course of the historical period from 1941 to 2001, there was a steady exit of firms from the LCS market, resulting in considerably less commercial influence on LCS and greater resemblance to a pure military-industrial complex. The capstone of this occurred in 1982 when the Chrysler Corporation reached an agreement with defense conglomerate General Dynamics Corporation for the purchase of Chrysler Defense Division, the prime contractor for the M-1 tank. The divestiture of this division by Chrysler severed its connections with tank development and production that had existed since before World War II.⁹ General Dynamics' newly acquired division was renamed General Dynamics Land Systems (GDLS). As the new sole producer of main battle tanks for the U.S. military, GDLS was now firmly entrenched as a dominant force in the LCS market. The following decade brought the end of the Cold War and widespread political pressure for a "peace dividend." The number of available suppliers decreased significantly during this period as many smaller firms lacked the flexibility to adapt to the changing procurement environment.¹⁰ However, at the prime contractor level, restructuring was elusive, and, in 1993, Secretary of Defense Les Aspin gathered 15 defense industry executives for dinner at the Pentagon for what would become known as "The Last Supper." During this gathering, Aspin informed industry leaders that the defense budget could no longer support the excess capacity existing in the defense industry and that DoD would not stand in the way of any corporate mergers or acquisitions necessary for market adaptations.¹¹ Aspin framed a stark reality: the choice between maintaining a large number of relatively weak competitors or a small number of healthy competitors.¹² The LCS industry responded to the new reality decisively. The first major merger occurred in February 1994 when FMC and BMY merged to form United Defense Limited Partnership (UDLP), with FMC owning 60% of the new company and BMY the remaining 40%. This merger created the largest U.S. supplier of light and medium weight tracked armored vehicles and along with GDLS, reduced the number of major LCS producers to just two.

Many of the commercial firms that were redirected into LCS production during World War II had vast engineering expertise; however, the Army maintained rigid design authority for combat vehicles during World War II. However, the advent of the M48 Patton Medium Tank during the Korean War heralded a new approach. Congress noted that the Army awarded Chrysler a "design engineering contract" for the entire production run of the M48 because the Army claimed it did not possess "design capacity" in either its arsenals or depots¹³. The M48 precedent would accelerate during this period. This was ultimately embodied in the development of the M1 Abrams main battle tank. Born out of failed joint efforts by Germany and the United States to develop a common tank to counteract perceived vulnerabilities to Warsaw Pact armor, new developments in armor plating, and lessons learned from the 1973 Yom Kippur War, Chrysler and General Motors developed competing designs for the XM1 and delivered prototypes. Chrysler won the down-select and entered government-funded development in 1976¹⁴. This shift to reliance on contractor design was not limited to tanks. On the M2 program, the FMC Corporation invested its own funds to develop multiple variants that ran counter to the Army's own preference for an armored personnel carrier. Ultimately, the combination of lessons learned from Vietnam and the Yom Kippur war, emergent needs to counter Soviet doctrine and tactics, and demonstrated performance brought FMC's design to the fore¹⁵.

This shift in design responsibility to the private sector was arguably cemented by the advent of technological advances chiefly emanating from commercial industry. Beginning with the 1980s, technology began to play a greater role in the LCS industry. Heretofore, U.S. combat vehicles countered Soviet quantitative edges by attempting to achieve edges in vehicle speed,

weapons range, or armor protection. As computer technology matured, information technology began providing the prime advantage over adversary forces. By the beginning of the decade, the Army had fielded technological advances like laser rangefinders, solid-state ballistic computers, and passive night sights on its front line heavy tanks.¹⁶ Ten years later, during Operation Desert Storm, the American technological advantage proved itself: Iraqi forces suffered high losses against a technologically superior force equipped with the latest night vision goggles, thermal imaging and satellite navigation capabilities.¹⁷ Superior firepower and numerical advantages were no longer the primary factors in determining victory. Technological superiority now played a major role, especially against an enemy incapable of countering this advantage.

As technology took root in major combat systems, the skills and strategies of the existing LCS producers adapted to keep pace with the evolving market. The core competencies of these companies could no longer just be automotive in nature. They shifted from producing large quantities of low-technology combat vehicles to smaller production runs of sophisticated weapon systems with much greater capabilities. The ability to produce armored combat vehicles with cutting edge electronic systems and the capacity to accept new components as new technologies appeared were key factors in the changing LCS industry from the 1980s on and directly led to the rise of the importance of the LCS prime contractor as a systems integrator.

This historical period did not merely transform the LCS industry, it also dramatically impacted the military's system of depots. The U.S. entered World War II with several well established manufacturing arsenals, some of which dated back to the Revolutionary War period. However, there were only five Army depots in existence in 1940¹⁸. The sheer planned size of our land forces in World War II and the still fresh memories of the logistical failings of World War I demanded a massive expansion of the depot system. By 1952, the Munitions Board accounted for seventy-one general depots and sixty-one branch-specific depots in the Army alone¹⁹. However, following the Korean War, sixteen Army depots closed. A similar trend occurred following Vietnam, when, by 1976, the Army depot system had contracted to seventeen domestic depots and two overseas depots²⁰. Later, in the 1980s, at the same time defense contractors were downsizing, consolidating, and merging to survive, government-owned depots were also looking for strategies to avoid being targeted by the Base Realignment and Closure (BRAC) Commission. In general, LCS depots were tasked with repairing, overhauling, and modifying existing combat vehicles. DoD could have diverted the limited level of work performed at the depots to the prime LCS contractors, clearly benefiting companies like UDLP and GDLS during the lean procurement years of the 1990s. However, this shift in workload would have cut depot infrastructure and sacrificed capacity that became invaluable as the Long War unfolded and surge was required beyond the capability of the LCS industry. Instead DoD encouraged private-public partnering within the construct of existing statutory requirements.

Finally, the 1930's and the dawn of our entry into World War II brought forth protectionist legislation that influenced the LCS industry. The first law, the Buy American Act (BAA), was passed in 1933. It required the procurement of American manufactured end items, and established a threshold of fifty percent of domestic content for each end item. The law places the burden of responsibility on the contractor²¹. For the fledgling domestic LCS industry in the 1940's, this legal requirement was not onerous, principally because converted automotive and other industries had largely domestic supplier networks. A more burdensome second law, the Berry Amendment, first appeared as a requirement embedded in the Naval Appropriations Act of 1940. The language established mandatory preferences for certain domestic commodities, initially food and textiles, in military procurement. Congress carried the substance of this

statutory preference forward from 1941 through this entire historical period. Again, this law was not initially problematic for the LCS industry because the covered commodities had minimal application to combat vehicles. However, in 1973, Congress added a new class of commodities, specialty metals (low weight, high strength materials), that had broad vehicular applications. Because regulatory implementation of the specialty metals preference included mandatory application at all tiers of subcontractors, this became a more onerous requirement for the LCS industry to meet, especially as Congress examined product compliance as a result of the Army black beret disclosures and as various Air Force non-availability determinations were scrutinized. The post-9/11 years have brought no progress on reconciling these statutory requirements to the reality that the LCS industry's supply chains are increasingly globalized.

In summary, as this defining period in domestic LCS history ended in 2001, powerful trends were manifest. The industry, which had expanded rapidly through the infusion of commercial companies during World War II, had experienced a steady contraction--by 2001, it was a typical military-industrial complex. This shaping resulted from a notable downward trend in production quantities coupled with ever-lengthening production runs that naturally contracted the industry. Consolidation was further demanded by DoD in the aftermath of the Cold War. In this period, there was a coincident shift in design authority from the military to industry, a shift cemented by the increasing complexity of LCS and the dependence on leading edge commercial technologies. In this period, there was a demonstrable decrease in government depots and the rise of private-public partnering. Finally, by 1979, the LCS industry was progressively impacted by protectionist legislation such as the Berry Amendment. In total, these factors defined the LCS industry that went into the Long War. History will be the final judge of how current military operations reshape the LCS industry; however, that history is already being written and it portends the future of this vital industry.

Current Conditions – Archetypical Industrial Response to Wartime Demands

The value of maintaining an industrial base is the ability to meet production requirements in the nation's time of need. The LCS industry's response to emergent improvised explosive device (IED) threats in OIF is the quintessential example of how an industry answers our nation's call. Evolving enemy threats and tactics in Iraq have driven changes in national policy and military strategy with ensuing resourcing and procurement decisions resulting in an increased demand for tactical wheeled vehicles. The need to better protect the troops provided a "burning platform" for the LCS industry to demonstrate its capability precisely at a time when many companies were literally hanging on for survival. Although Secretary of Defense Donald Rumsfeld had in effect, sounded the death knell for the LCS main battle tank segment with his aggressive transformation initiatives, the bell tolled for him the moment he uttered those now infamous words, "you go to war with the army that you have." That fateful moment rang in a rebirth of the tactical wheeled vehicle segment and industry's response over the past three years has been prolific.

The state of the LCS industry is healthy, much improved compared to pre-war conditions, and enjoying a funding feast in stark contrast to the late 1990s famine environment. The utility of armored vehicles has expanded throughout the entire spectrum of war, increasing the future demand for this LCS market segment. The industry has responded well to wartime requirements in spite of government funding and regulatory vagaries, and in most cases has

surpassed heightened expectations with depot and OEM capacity still untapped. In fact, some industry experts believe supply shortages have been government induced.

The DoD is attempting to overcome these impediments by making the Mine Resistant Ambush Protected (MRAP) vehicle program the nations #1 acquisition priority, exempting the program from a handful of criteria new weapon system programs normally must meet. Actions include waiving a mandate for networked operations and excusing an information support plan, communications architecture, and a new concept of operations requirements. Granting this relief is central to facilitate acquisition of nearly 8,000 new armored vehicles over the next 18 months that promise improved protection against IEDs.

Industry has faced significant challenges adjusting to the time lag from requirement to contract award, and delays from contract award to production start up attributable to Berry/Special Metal requirements and reticence to use DX ratings to place military needs ahead of commercial requirements. Under Title I of the Defense Production Act of 1950 (DPA), the President is authorized to require preferential acceptance and performance of contracts or orders supporting certain approved national defense and energy programs. The purpose of the Defense Priorities and Allocations System (DPAS) is to (1) assure the timely availability of industrial resources to meet current national defense and emergency preparedness program requirements; and (2) provide an operating system to support rapid industrial response in a national emergency. Currently there are only two LCS programs on this list: M1 Abrams, and Counter IED CREW.

It would be remiss to provide LCS a “fit” bill of health without a more detailed examination of industrial strength reminiscent of a thorough physical exam. This seminar’s assessment of the vital signs include resourcing, supply shortages, fleet maintenance/upgrade, workforce, markets (domestic/global), facilities (industry/government), R&D, and trends like lead system integration (LSI). Wartime performance and industry trends offer a more refined diagnosis and a better prognosis for future vitality.

Resourcing

The current Future Years Defense Program (FYDP) is indicative of a wartime posture. In addition to modernization and transformation programs, the FYDP projects an extended period of intensive legacy systems RESET/recapitalization. Despite this, industry and depots cite supplemental budgets as the largest funding source of the current workload. They recognize, however, that supplementals are temporary, and are taking prudent measures, such as the use of overtime and contract labor, to mitigate the effects of a post war return to a normal appropriations environment. Additionally, supplementals have significantly complicated acquisition because of their inconsistent timing, and have caused production delays and schedule perturbations. Because of this dynamic, risk has shifted to contractors, and, in some cases, they used corporate funds to procure long lead material or provide labor continuity. This assumption of risk has been heightened by the reluctance of our military services to employ the full complement of acquisition tools at their disposal to preserve production schedules (e.g., letter contracts, long lead or advance procurement).

Supply Shortages:

LCS supply shortages in support of the war did not result only from problems of industrial capacity. Such shortages are dependent on the specific material being discussed. According to a 2005 Government Accountability Office (GAO) report, “Defense Logistics” both ceramic armor and Kevlar do, in fact, have limiting production factors caused by raw material

and legal constraints²². The GAO blames problems in planning and procurement for other supply shortages. Specifically, the GAO attributes tire shortages to an inefficient DOD procurement system and lack of adequate inventory planning. A review of other critical components showed similar issues, most notably that ballistic windshield shortages were due to the inflexibility of the DOD procurement system and transmission shortages were attributable to the inability of the procurement system to accommodate dual use commercial products.

Short-term ballistic steel shortages have impacted some LCS vehicles, but it is questionable whether the cause is a lack of U.S. steel production capacity or raw materials. The GAO places more of the blame on inefficiencies in the procurement system. The GAO concludes the root causes that make it nearly impossible for the U.S. steel industry to maintain excess production capacity are inadequate, insufficient, and delayed funding; inaccurate supply forecasts; and acquisition delays. There are currently only two U.S. ballistic steel suppliers, both of which are foreign owned, that have proven to be resilient in response to long term DoD demands. Although the U.S. steel market as a whole is affected by cheaper foreign commercial products, the proven ability to supplement short term DoD demand requirements with Canadian steel has helped by reducing the necessity to maintain idle U.S. ballistic steel production capacity. This has allowed DoD to fulfill demand requirements while buying time for U.S. production to react and respond over the long term.

Fleet Maintenance/Upgrade

Periodic refurbishment of military vehicles, or "RESET" is a normal part of system maintenance. While the scope of RESET work varies, the most extensive programs restore vehicles back to a like-new zero-hours, zero miles (0/0), condition. The Army uses a seven year interval between 0/0 RESETs for system lifecycle planning. During times of war, when the vehicle use/mileage is extensive that interval can be shortened to as little as one year. RESET is typically performed at Government Depots or at contractor facilities.. Most contractors see tanks, armored fighting vehicles and truck RESET as a growth industry supplying more than 50% of their revenue stream in the next 5-7 years, even as new systems like FCS and EFV enter production.

Workforce

Labor in the LCS industry is relatively stable but changes commensurate with industry output. The multi-tiered work force of permanent employees, contractors, and temporary hires has met the market surge superbly, with an increased reliance on contractors and temporary hires. Contractors and depots are hiring the best of these temporary workforces permanently, providing a boost in quality and reducing the average age of their employees. GDLS and BAE are also taking advantage of lay-offs in the auto industry to hire engineers and skilled technicians. These trends run counter to those of U.S. labor in general, where there is growing concern over diminishing skills in the workforce, especially in ballistic welding, R&D, and engineering. Although the U.S. workforce in general is aging, employees with tenure and experience continue to add value to the industry. Nonetheless, there is a tipping point where the work force is too old, and it remains to be seen whether current hiring will ensure a stable LCS industry workforce in the future.

Markets and Globalization

The major producers in the LCS arena are global competitors, and they face increasing burdens from those countries that issue protectionist legislation to maintain their own markets. The following section on the European industry will elaborate on this theme. Although LCS does not meet the Organization for Economic Cooperation and Development's formal definition of a globalized industry, the LCS supply chain is recognized as a highly globalized segment with implications for national defense. Domestic LCS companies' market share may decrease as foreign companies with cheaper alternatives become more competitive and adaptive. As an example, the European Union created the European Defense Agency (EDA) to consolidate and preserve the European Defense Technological and Industrial Base (EDTIB), in part to enable them to compete with the United States globally.

Depots

The LCS depot system has responded well to the surge in demand during the current conflict. There are two primary LCS maintenance depots. Both are government owned, government operated (GOGO) Army depots (Anniston Army Depot [ANAD], Anniston, AL and Red River Army Depot [RRAD], Red River, TX). Letterkenny Army Depot [LEAD], in Letterkenny, PA, is another GOGO depot the Army is using for temporary HMMWV RESET. DoD also has two GOGO Marine logistics bases (Marine Corps Logistics Base [MCLB] Albany, Albany GA, and MCLB Barstow, Barstow CA).

All of these facilities have increased dramatically their maintenance activities in support of the war effort; they will remain valuable assets in the near term, with RESET/recap activities continuing for years after hostilities diminish. The depots are competing to attain product supremacy through various quality and product reform initiatives; however, facility recapitalization and refurbishment continue to be significant challenges. Further discussion of depots can be found in Appendix 1.

GOCO Facilities

One site is a joint service government owned contractor operated (GOCO) facility, the Joint Systems Manufacturing Center (JSMC) in Lima, OH, operated by General Dynamics Land Systems (GDLS). GOCO facilities like this one are valuable to the defense industrial base. Despite their importance, neither the U.S. government nor industry in general is sufficiently investing in GOCOs to sustain these facilities and their unique tooling. The exception to this observation is the current upgrade and installation of new tooling at Lima to support the USMC's upcoming Expeditionary Fighting Vehicle (EFV) production line.

Research and Development

Research and development (R&D) funding in the U.S. LCS industry has remained relatively constant. So too have engineering and science research endeavors. The Future Combat Systems (FCS) is an anomaly, a large temporary increase in R&D funds to design several interrelated weapon systems; integration of new and challenging technologies will continue to evolve from this program. As tactical wheeled vehicles become more technologically advanced, heavier emphasis will be placed on future R&D investment. Many industry experts believe that other countries have more talented engineers and scientists. This is offset by the DoD's higher level of R&D spending to develop technological advances, advances that maintain the United States' competitive advantage in this arena. Continued consolidation of the industry abroad and

globalization will cause many R&D streams to move offshore in some key sub-industries, making it more difficult for the United States to retain its advantage.

Rise of the Lead Systems Integrator (LSI)

Many industry experts believe that the government does not have the personnel to manage programs requiring complex integration of systems from multitudes of defense contractors. The LSI approach enables the government to integrate the best of what industry, DoD and the services provide, competitively selecting industry-leading partners to develop systems based on system-of-systems architectures. Boeing's selection as the LSI for FCS is an example of this new approach. It is also an example of market penetration by an outside competitor "hired" into the industry because of their demonstrated innovative technologies and state of the art capabilities. Boeing and others may see a future market as "referees," especially as systems and programs get more complex and costly, and the government's ability to manage such programs weakens. This trend changes LCS industry entry dynamics, which traditionally had been predicated on *market production* and may now be about *market integration*.

European Market for Land Combat Systems

Since the end of World War II, the political, economic, and military industrial landscape in Europe has evolved significantly. Simultaneously, the land combat systems (LCS) industry in Europe also has been changing at a pace that is even more radical than that of Europe. As Europe has been evolving from its Cold War posture into the European Union, the LCS industry has been growing from a static environment of nationally based industries producing nationalist weapons programs feeding home grown, inefficiently structured industries. This change represents a move to a dynamic environment that, on the surface at least, is capable of achieving cross border cooperation and developing common and interoperable systems that are joint and more competitive with the United States.

Post World War II, the top priority in Western Europe was to rebuild domestic economic and political infrastructures. However, the Cold War made military rearmament a strategic priority and many of the more heavily affected, smaller European nations lacked the resources for simultaneous economic recovery and a military build up. To assist in that rearmament, the U.S. initiated a program of military aid to its European allies, the Marshall Plan.²³ U.S. aid was not limited to the sales or donations of surplus stock, but also assistance in the development of domestic European defense industries. The buildup of national defense industries meant increased self-reliance as well as improved technological, industrial, and employment opportunities in the new Europe.

Technological developments in Europe increased at a rapid pace during the Cold War. The costs of developing and producing complex new weapons systems began to be felt throughout Europe, yet the LCS industry stayed nationally focused. Attempts to conduct cross border development and production collaboration failed to come to fruition. Major European arms-producing countries continued to develop and field their own systems, from artillery systems to armored vehicles, throughout the Cold War.

Recognizing that no single country could sustain a national defense technological industrial base (DTIB) that could meet all of its needs and remain viable, and that there were too many companies chasing too few contracts, European industry leaders decided consolidation was the only real course of action. Governments realized that they had to make their strategic

priorities clearer and coordinate their procurement decisions better.²⁴ The discrepancy between flat, stagnating investment budgets and increasing system costs has had a two-fold damaging effect. First, critics believe a gap in Europe's military capabilities has become evident. These critics argue that Kosovo and Afghanistan revealed European armed forces are inadequately equipped for modern warfare. Second, the limits on military spending are increasingly damaging to the EDTIB. Lack of investment in particular is jeopardizing the LCS industry's technological ability to prepare for the future.²⁵

Comparing the EU and U.S. defense budgets illustrates the problem. According to Richard Bitzinger, a defense analyst, the EU spent €26.4 billion (\$35 billion) on procurement in 2005, and €9 billion (\$11.8 billion) on R&D. By way of contrast, DoD spent approximately \$103 billion for procurement and \$71 billion for R&D during the same period. Bitzinger points out that "the U.S. spent nearly three times as much on equipment as the EU combined, and more than six times as much on R&D."²⁶ France and the UK military spending grew by five and six percent respectively during the five years before 2006. During the same timeframe, U.S. defense spending grew by over 40%, not including supplementals.²⁷

Simultaneously, European governments realized their companies could not compete against each other, let alone the U.S., without some form of consolidation. Thirteen countries with thirty-five major land system companies possessed a capability of designing and producing armored vehicles. Industrial consolidation throughout Europe has been slow and has followed different paths in each country. Only recently have the traditional, national powerhouses, BAE (Great Britain), Rheinmetall (Germany), Kraus-Maffei Wegmann (KMW, Germany) and Nexter (formerly GIAT, France), recognized that survival required consolidation. Smaller LCS companies either joined forces or were acquired by global firms like GD and BAE. During the last several years, there have been a number of joint ventures, mergers, and acquisitions amongst the LCS-producing companies. This restructuring occurred irrespective of national borders, creating greater capability in the industry, though the consolidation still falls short of that seen in the United States.

Contrasting the U.S. and European LCS industries reveals important strengths and weaknesses. Because the U.S. market can be very profitable, it attracts considerable competition, with the corresponding capital investments. As a result of this competition, as well as DoD investments, the U.S. technology base is strong while the European base is more fragmented between countries. This emphasis on cutting-edge technology can be a weakness, though. The U.S. DoD tends to look for "paper solutions" rather than existing products that can be delivered immediately. This can lead to schedule delays and cost overruns.

One industry leader presented additional contrasts in the U.S. and European business models. The European system believes in establishing long-term relations with its customers; DoD does not enjoy similar relations due to the high levels of competition within the industry. Europeans tend to use cost-plus contracts only in the early phases of research, shifting to firm fixed price (FFP) contracts during system design and development (SDD) and production. DoD tends to use cost-plus contracts through SDD, using FFP contracts only during production. This difference reflects the DoD emphasis on cutting-edge technologies. In the United States, funding cycles are annual; in Europe, funding is appropriated for each phase of a program, over multiple years, resulting in greater program stability. Finally, DoD requirements frequently change during a program, causing cost growth and schedule delays, while European funding constraints force them to far greater fiscal discipline.

The European LCS industry is positioned well, at this time, to capitalize on its consolidation efforts and technological programs such as the U.K.'s Future Rapid Effect System and Sweden's SEP program. The prime movers in the industry will have to continue to cooperate with the governments of the EU to leverage these opportunities. Governments must also allocate the appropriate amount of funding for R&D and procurement. Competition is the only way to enhance the EDTIB and keep the European LCS industry growing.

Future Demand for Tactical Wheeled Vehicles

The outlook for TWV is driven by many trends: an aging fleet, a useful life shortened by the Global War on Terrorism (GWOT), combat losses, fleet capabilities insufficient for the future battlefield, and the increasing size of the Army and USMC.

Current Conditions of the Tactical Wheeled Fleet

The Army estimates it manages over 200,000 tactical wheeled vehicles and an additional 85,000 trailers.²⁸ The USMC controls well over 25,000 tactical vehicles and trailers. Although these two services represent the two largest consumers of the TWV market, all services and many non-DoD organizations have a requirement for tactical wheeled vehicles. While it is impossible to truly capture the entire cost of this market, the Army has estimated its assets alone amount to over \$36 billion in capital costs.²⁹

Due to the war on terrorism, many of these TWVs are forward deployed and operating under some of the most adverse conditions in places like Iraq and Afghanistan. Operations such as these have highlighted some of the deficiencies in these systems. First, the TWV fleet is aging beyond its useful life. Over 50% of the Army's existing TWV fleet is approaching, or has exceeded, its Economical Useful Life (EUL).³⁰ Second, DoD is losing vehicles in combat while requirements for TWVs have increased. Third, the capabilities of the current fleet will not allow effective support to the services.

Future Drivers of Demand

Future drivers of demand for TWVs include a new emphasis on survivability, the need for reset and recapitalization, and the DoD plans to modernize and modularize its forces. The annual budget for TWV support in the past (FY 2000-2004) has fluctuated around the \$1-2 billion mark but the current FYDP plan (FY 2007-2011) shows the willingness of the DoD to increase this support to around \$11 billion a year.³¹

Casualties in Iraq and Afghanistan have driven a demand to harden trucks that previously have not been considered combat vehicles. DoD speakers at the National Defense Industrial Association's (NDIA) 2006 TWV conference informed industry and the media that, starting in FY07, every new TWV regardless of variant will have A-kit armor and be fitted for B-kit capability. Commanders in the field are also requesting as an urgent need a requirement for a Mine Resistant Ambush Protected (MRAP) vehicle that will further drive near-term demand. The total U.S. military requirement for MRAP--a stopgap for the HMMWV replacement--has surged to 7,774 vehicles with an estimated cost of \$7-8 billion³², with unconfirmed reports that the Army will request 17,770 vehicles costing as much as \$25 billion.³³ In order to satisfy this requirement and get the vehicles into the hands of the warfighter as soon as possible, the services are asking industry to produce these vehicles at the rate of 400 vehicles a month.

Reset and recapitalization will also drive future demand. As the United States eventually pulls out of Iraq and Afghanistan, combat equipment will need to be reset or replaced. This endeavor, however, will not take place overnight. As history shows, it took the Army almost two years to reset its forces following DESERT STORM, a conflict that lasted only 6 months. The USMC agrees, estimating reset could take several years.³⁴

A final driver for demand will be the Army's modernization and modularity plan. The U.S. Army, National Guard, and reserves are undergoing a structural change from 58 combined Brigade Combat Teams (BCTs) to 72 by 2007. In addition, the Army is increasing the number of vehicles in each BCT. The Army has also been given authorization to grow its active duty end-strength by 65,000 and the reserve by 9,000 by FY13.³⁵ The final objective is to be lighter, more mobile, and self-reliant. The Army expects that it will require the addition of 40,000 more vehicles to its current fleet to meet the requirements of this larger and more modular force. Just as the Army is growing, the USMC has also been authorized an increase to its end-strength by 22,000 Marines and it too will need additional supplies and equipment to support them.

Modernization is also driving more technologically sophisticated TWVs. The Joint Light Tactical Vehicle (JLTV) program requires high survivability in light vehicles, driving industry to experiment with new materials and designs. High-tech solutions like active defenses may also be required, at least as an option. Such sophisticated TWVs make the JLTV market interesting to large defense contractors like Lockheed Martin.

The ongoing conflict in Iraq and Afghanistan, the new emphasis on survivability, the eventual need to reset and recapitalize the TWV fleet, and the drive to modularize and modernize the force will combine to ensure a dramatically increased demand for TWVs.

Future Demand for Wheeled and Tracked Combat Vehicles

Army Plans

The Army is pursuing a two-tiered strategy to modernize its current fleet of Wheeled and Tracked Combat Vehicles (WTCVs), while simultaneously developing a new family of WTCVs called the Future Combat System (FCS). Under this strategy the Army will equip approximately half of its Heavy Brigade Combat Teams (HBCTs) with the most advanced models of M1 tanks and Bradley fighting vehicles, while the remainder will have less advanced (and less expensive) variants. When the FCS enters the force in 2016, it will displace the equipment in the less advanced HBCTs leaving the Army with 15 FCS-equipped Brigades and 18 HBCTs³⁶ equipped with the most modern Abrams tanks and Bradley Fighting Vehicles.

To meet current combat needs while continuing to modernize, the Army is using RESET funds (primarily Operations and Maintenance) to refurbish Abrams tanks to the latest M1A1 AIM standard³⁷. Concurrent with this, the Army is using RECAP funding (mostly Procurement) to upgrade other tanks to the more costly M1A2 SEP standard³⁸. The M1A2 SEP tanks have a more advanced fire control systems and upgraded electronics. In a similar vein, some Bradley Fighting Vehicles are being RESET to the M2A2 latest ODS standard³⁹, while others are being upgraded to the M2A3 standard⁴⁰. In 2015 the Brigades equipped with the M1A1 AIM and M2A2 ODS vehicles will begin turning in their tracks and drawing the next generation of WTCVs, the Future Combat System. The phase out of older tanks, and the introduction of the FCS is shown in more detail in Appendix 2.

One new RESET and upgrade path that may portend the way of the future for current force vehicles is that of the M109A6 Paladin 155mm howitzer. The latest Army plans call for approximately half of the Army's Paladins to be RESET to the current configuration, while the

other half is upgraded. The proposed Paladin upgrade involves mounting the current Paladin turret in an entirely new lower hull. The new hull will accommodate the Bradley engine, transmission and track. That upgrade addresses obsolescence issues facing the current Paladin drivetrain, and provides greater commonality of parts within the HBCT. The new lower hull also provides more stowage, is surprisingly inexpensive (cheaper than a rebuilt Paladin transmission), and will result in lower life cycle costs because the Bradley drivetrain is cheaper to maintain.

The idea of replacing turrets or hulls as part of an upgrade is not new, but it may become a more common way to upgrade current force WTCVs. The current M109A6 Paladins were built in the 1990's by mounting new turrets on hulls of older model M109s built in the 1960s and 1970s. Once the Paladin turrets are mounted on the new Bradley-drivetrain hulls, there will not be any original M109 metal in the howitzers. Since M1 Abrams tanks and Bradley Fighting Vehicles will remain in the force until 2050, it could be the case that future upgrades to those vehicles involve replacing their hulls and/or turrets with more capable versions.

41

The Future Combat System (FCS)

FCS is the flagship of the Army's modernization program. FCS is a "system of systems" that includes a family of eight WTCVs, soldier enhancement systems, and unmanned ground and aerial vehicles, all integrated by a comprehensive tactical communications network. The WTCVs in the FCS system include a tank-like Mounted Combat System, Infantry Carrier and Reconnaissance & Surveillance Vehicles that will fill a role similar to the M2 (Infantry) and M3 (Cavalry) Bradley Fighting Vehicles, and a Non-line of Sight Cannon with a 155mm howitzer similar to the one found in the Paladin⁴². Recovery and Maintenance, Mortar, Medical, and Command & Control variants of the FCS will fill roles currently performed by M88A2 and M113 derived vehicles in the current HBCTs⁴³. While the FCS vehicles will fill roles akin to their current force counterparts, they will do so while being lighter and more easily deployable. They will also have greatly reduced manpower requirements compared to current force WTCVs.

The prime contractor and LSI for the FCS program is Boeing, but GDLS and BAE Systems Inc. are teamed in the design of the manned ground vehicles portion of FCS. BAE Systems is responsible for the design of the Infantry Carrier, Medical, Recovery and Maintenance, Mortar and Non-line of Sight Cannon variants. GDLS is responsible for the design of the Mounted Combat, Reconnaissance and Command & Control variants. The companies are working together to maintain an extraordinarily high degree of commonality between the vehicles.

Because the FCS vehicles are designed around a common lower hull and drivetrain, the FCS equipped brigade will have the advantage of a high level of parts interchangeability between all of its tracked vehicles, simplifying maintenance and spare parts stockage requirements. It will also greatly simplify operator and maintenance training requirements. While the Army's current focus is on developing and fielding the FCS, eventually those systems will need to be refurbished and even upgraded. At that point in the system life-cycle, the commonality between the various FCS vehicles should also help to keep RESET and upgrade costs lower than what they would be if the Army developed each vehicle independently. The commonality of the vehicles may also allow for increased competition for vehicle refurbishment and upgrade contracts.

Achieving these reduced life cycle costs will be difficult if development challenges continue to cause costs to grow. FCS is a technologically challenging program; the GAO has even criticized DoD for entering development with technologies that weren't ready for system

design. Supporters of the program argue that such aggressive planning is necessary to ensure delivery of cutting-edge weapon systems to the warfighter at the earliest possible date. Currently DoD's second largest program, FCS has seen significant cost growth, causing the Army to eliminate some of the lower priority systems.

USMC Plans for Wheeled and Tracked Combat Vehicles

The Marine Corps doctrine of Operational Maneuver from the Sea (OMFTS) is driving procurement of the EFV and influencing the upgrade of the rest of the WTCV fleet. OMFTS calls for launching amphibious vehicles from ships that are beyond the horizon (up to 25 miles) from the objective beachheads. The EFV is well suited for this mission because it can swim at high speeds over great distances, even in relatively rough seas. The older AAV's can swim as well, but they are limited to much slower speeds, making them vulnerable during over-the-horizon swims. Other Marine WTCVs, such as LAV-25s⁴⁴ and M1 tanks rely on the Landing Craft, Air Cushion (LCAC, a high speed cargo hovercraft) for transport from ship to shore. If the EFV program is cancelled it will have a detrimental effect on the USMC's ability to execute their OMFTS doctrine.

In addition to developing the EFV, the USMC has been modernizing their current fleet of WTCVs by leveraging the Army's AIM program to upgrade their Abrams tanks and mounting a Bradley derived engine in the AAV to increase power and reduce maintenance costs. The projected demand for WTCV in the Army and USMC will be a major factor in the future of the LCS industry.

Future of the Land Combat Systems Industry

Pressures on Funding for Land Combat Systems

Combat operations in Iraq and Afghanistan will someday either draw to a close or diminish significantly, leading to reduced funding for DoD with potentially dramatic implications for the LCS industry. When the war ends, supplemental appropriations will also. DoD will have to compete with rapidly growing entitlement programs like social security, Medicare, and Medicaid.

Within DoD there will also be pressure to reduce funding for land combat systems. Just as the threat of conventional armies diminished in the late 1980s, some people think the future will see a decrease in the threat of terrorism. Others believe that nation building will be more important than deterring near-peer competitors like China. Many policy makers will continue to recognize the criticality of maintaining a flexible ground maneuver capability and a supporting industrial base that is able to surge with emerging threats to our national security; many will recognize this, but not all. Debates will rage about the proper defense structure to meet either the coming threats, or provide the appropriate capabilities, to defend the United States. Politicians from both parties have supported increasing manpower for the Army and the Marines; costs for this manpower, estimated at \$76.3 billion by 2013 for the Army and \$31.7 billion for the Marines, will compete with procurement funding.⁴⁵ Resetting the force after combat operations will also drive large costs, up to \$13 billion annually for three years after combat ends.⁴⁶ At the same time, foreign military sales of U.S. LCS are likely to shrink as former customers like South Korea become competitors. The result will almost certainly be less funding for land combat system procurement. In future periods of national emergency, the United States will require a

more responsive appropriations process to ensure timely fielding of urgent capability and to preclude industry from having to assume undue financial risk.

These likely funding reductions will force the U.S. Army and U.S. Marine Corps to make difficult decisions about land combat systems. Despite confident statements by Pentagon leadership, the Army may not be able to afford the ambitious programs described in previous sections. Soldiers may have to choose between procuring the FCS, modernizing the HBCTs and Strykers, and increasing survivability requirements for its tactical wheeled vehicle fleet. FCS is the second most expensive program in DoD, and has already seen scope reductions; future reductions may still occur. It is possible the program will result only in technology spin-offs. Modernizing the HBCTs and Strykers is less technologically challenging, so these programs are more likely to survive. Combined with the Marines' expensive but more mature EFV program, DoD will have to make tough decisions in the coming years.

As DoD reevaluates its procurement programs, reduces delivery demands, and reacts to the inevitable elimination of supplemental funding, it must recognize the implications on the land combat industry. New production and resetting of the fleet may diminish, causing a reduction in the work force and potential impact on new developments, to be addressed in the next section.

Where is the LCS Industry Going?

Looking out five years, it is reasonable to expect business conditions for the land combat industry to slow down new production and upgrades to existing systems. The industry during this time will continue to benefit from current requirements driven by OIF/OEF refurbishment and the increase in both USMC and Army end-strengths. However, it is likely that the surge requirements will slow down during this timeframe. Projected near term business will remain stable, but this will be a critical time to establish relationships with industry and create an atmosphere of confidence between government, industry and the labor workforce.

The somewhat bleak outlook beyond the next five years implies that DoD may not be able to maintain its current investment in R&D and continue supporting the industrial base at its current capacity. Where DoD invests its funds will determine the future of the industry. DoD's past emphasis on sustaining technological advantage will likely continue, implying R&D funding will continue relatively constant as it has in past drawdowns. DoD will therefore have to decide where to consolidate the industrial base.

Industrial base consolidation for OEMs and depots could take many forms. It will be important for DoD to ensure that the consolidation effort does not result in such a small number of companies that competition is jeopardized. The OEMs and depots will compete for scarce modernization funds. Both will lay off contract employees, returning to workforce levels before the wartime surge. Lower production volumes at the OEMs and depots will cause overhead rates and other fixed costs to increase the unit costs. These cost increases will drive the Army to reconsider whether it can afford to have four major production sites: BAE in York, GDLS in Lima, Red River Army Depot (RRAD), and ANAD. BRAC may also drive closure of one of the depots. Another possibility is requiring BAE to cohabitate with GDLS in Lima, especially if both OEMs engage in FCS production with its promised parts commonality.⁴⁷ The Army may also encourage JLTV production at Lima or York rather than creating a new production location.

Industry will probably undergo a period of consolidation as it did in the 1990's. There were fewer providers than in the 1990's, especially in the WTCV market. The award of the production contracts for the manufacture of the FCS manned combat vehicles will have a profound effect on the industry. Will Boeing be involved in production, or will the Army

contract directly with BAE Systems and GDLS? Where will production of the common lower hull take place, Lima or a BAE facility (e.g., York, PA), or both? If either contractor is cut out of lower hull production, it could significantly weaken that contractor's standing in the LCS market. It will be important for DoD to ensure that the consolidation effort does not result in such a small number of companies that it limits open competition. Further consolidation of the combat vehicles seems unlikely, but is likely to occur in tactical wheeled vehicles. GD or BAE may also decide to diversify into producing these lighter vehicles now that they are becoming combat vehicles with more technological influences. In fact, BAE recently announced it was buying the LTV manufacturer Armor Holdings.

The industry will face decisions about maintaining a viable workforce, investing in new technology, and shifting business to commercial activities and potentially overseas. The vendors and subcomponent manufacturers supplying the industrial base will also face a reduction in demand, causing many to close or shift to commercial products. Globalization has already moved production of many automotive components offshore; this trend is likely to continue, implying that manufacture of land combat system components will also increasingly come from overseas. Compliance with the Berry Amendment/Specialty Metals requirements will therefore become increasingly expensive and out of place in a globalized industry. The U.S. Government will be faced with a decision whether to continue these expensive protectionist policies, which also hinder the nation in time of war, or embrace globalization and seek to manage the accompanying risks. The defense spending draw down will also mean that Allison's Plant 14, where they manufacture and rebuild military transmissions, will again suffer from a workload reduction; Allison may question whether to remain in the business of military transmissions unless DoD can provide sufficient workload, as they have in the past.

Robotics

The LCS robotics market is a fledgling market with great potential for future growth. As technologies continue to advance, the increased ability of robots to substitute for humans in the performance of dangerous, mundane, or monotonous tasks has led to a much greater demand for military robots. Although robotics is currently a niche market in the LCS industry, the successful military applications of robots in Afghanistan and Iraq have proven their utility and it is unlikely DoD will ever go to war without battlefield robots again. Although market entry is difficult, there are currently five major companies that appear capable of integrating and fielding unmanned ground systems. Three are major defense companies (General Dynamics, Lockheed Martin, and BAE Systems), one is a truck company (Oshkosh) and the last is a consumer robotics company (iRobot). Currently, competition in this market is limited since iRobot is the only supplier with a fielded robotics system in combat in Afghanistan and Iraq.

The U.S. Congress believes unmanned vehicles can and will play a major role in shaping the military forces of tomorrow. Congress has set a goal for the Armed Forces, to make one-third of operational ground combat vehicles unmanned by 2015. It remains to be seen if the robotics industry will mature quickly enough to meet this mandate. Although direct product competition is limited right now, competition will increase as unmanned technologies continue to mature and new market entrants emerge with robotic products that have both military and commercial applications. As these robots continue to prove their worth, suppliers will need to continue investing in research and development to improve the level of autonomy and the combat capabilities of unmanned systems.

DoD will face major decisions about the land combat systems industrial base as the current wartime surge abates. The resulting structure, conduct, and performance of the industry will determine whether it is ready for the next wartime surge. Recommendations for these decisions follow in the next section.

Recommendations

The United States needs to address the role of the defense industrial base in its national strategies, then communicate those strategies to industry. Strategy development begins with the President's National Security Strategy (NSS). The NSS fails to provide language about the importance of the defense industrial base. The nation's security relies in part on the industrial base to provide the military with the means to confront enemies throughout the world. DoD should work with the National Security Council to develop language that is nested throughout our top-level national strategy documents for addressing future requirements. This strategy should identify existing threats, potential threats, and the expectation of the role of ground combat forces to address those threats. DoD should use this strategy to ensure it maintains an industrial base during peacetime. DoD will need to consider this strategy when making major source selection decisions, like award of the FCS production contracts. DoD should document and convey the long-term threat analysis to industry to insure that R&D investment is directed toward developing technologies and systems that are responsive to perceived requirements. Involvement of the LCS industry will improve the development process.

DoD should work with Congress to establish better ways to fund procurement in time of war. The POM cycle, even with supplementals, does not respond quickly enough. Congress should authorize an emergency fund during a national crisis, giving DoD authority to purchase critical weapons like MRAP, up-armor kits, and body armor. Annual supplementals, if needed, should provide funding earlier in the fiscal year to keep contractors from having to go at risk to meet wartime requirement. Long lead procurement rules should be more flexible, allowing DoD to procure a limited quantity of supplies in order to jump start critical acquisition programs. DoD should also request statutory authority for the Secretary of Defense to waive Berry Amendment Strategic Material restrictions during times of national crisis. DoD should ensure it is exploiting all currently available provisions for waivers. DoD needs to expand its list of DX programs to include mission critical LCS platforms to be identified by the Army and the Marine Corps. DoD should establish a process for expediting requests for changes in DPAS rating or establishing a DPAS rating for a new program during wartime or national emergency. DoD should also ensure they use all available acquisition tools (e.g. letter contracts, long-lead procurement, and advanced procurement) to shorten lead times and maximize the benefits of supplemental funding.

The United States needs to reassess restrictions on buying foreign steel. The Berry Amendment restrictions on DoD purchases of foreign steel need to be revisited. The United States should consider relaxing restrictions on foreign steel purchases and utilizing overseas sources as a "third tier" supplemental provider for the U.S. ballistic steel market. This would allow the DoD to save money in the short run with cheaper, foreign produced ballistic steel and help to stabilize the short term price of both U.S. and Canadian steel during times of increased demand. Changes in these areas would lead to a more profitable, healthy, and productive U.S. ballistic steel manufacturing market.

DoD will need to address its depot infrastructure, including GOCO facilities like Lima, as workload decreases. DoD should recapitalize its depots and GOCOs; the department needs to

appropriate more funds for facilities maintenance, especially at Lima. An alternative for Lima could involve putting GD on a performance-based service contract for facility maintenance as well as weapon system production, manufacturing, and refurbishment. DoD could provide award fee incentives for tooling improvements that result in cost savings and productivity increases. The seminar was divided on whether the depots will need further consolidation. Some value the excess capacity because it provided the ability to surge to meet the current wartime needs. Others believe such surge capacity could come from commercial sources, if government acquisition regulations were properly adjusted.

DoD should demand high-tech solutions only where needed. DoD should not lose sight of opportunities to use commercial solutions, especially in the TWV fleet. The emphasis on armoring and networking the entire fleet is overly ambitious. Some of the fleet requires these capabilities, but not all of it. In general, in cases where DoD has unique technology requirements and product niches, it must be prepared to bear the full cost of maintaining a separate and unique industrial base. In other cases, however, many problems can be solved by revamping the procurement system to make it easier for companies to sell solutions to military problems using commercial technology. Such approaches would allow DoD to follow the lead of European agencies and use more FFP contracts.

DoD should continue its emphasis on modular and common systems. Modularity and commonality should be included from the beginning to drive down the total life-cycle costs. As weapon systems become more expensive, the nation will not be able to buy as many end-items and therefore will demand multi-role systems. Evidence of this theme is seen across the LCS spectrum including Stryker variants, the Future Combat System, and JLTV.

Conclusion

The seminar surveyed the state of the U.S. Land Combat System industry. Since national security is a public good, the U.S. Government bears the responsibility of providing a military force supporting that security. DoD doesn't merely purchase weapon systems; each procurement also funds maintenance of an industrial base during peacetime that needs to be ready to support the nation during time of war. Since World War II, the LCS industrial base evolved from a series of specialized government arsenals to a combination of government depots and commercial enterprises. The study found that the current LCS industry has responded well to the demands of wartime production. Funding fluctuations, Berry Amendment requirements, and long lead times contributed to delays in some procurements, leading the study to make recommendations for improvements to wartime acquisition processes.

In the near future, the demand for TWV will increase as the Iraq conflict has led to a new emphasis on survivability. Commanders want their trucks armored, networked, and carrying weapons. Current plans also call for an increase in the demand for WTCVs, as RESET and modernization continue on current systems, and production of EFV and FCS begins. A combination of budget problems make it unlikely, however, that DoD will be able to afford to fund all its programs while retaining its current industrial base. DoD may have to make hard decisions about whether to consolidate government depots, and the drop-off in funding may cause more mergers and acquisitions in industry. DoD should take care to ensure these mergers retain two viable LCS providers as a minimum.

Most importantly, the leaders of the United States need to recognize that the defense industrial base is a key requirement for a strong nation, and take steps to incorporate that

requirement in the nation's security strategy. The United States must manage the industrial base during the inevitable funding drop-off if it wants to be ready for the next war.



Appendix 1—LCS Depots

Most depots originated between World War II and the Korean War years. The U.S. government believed that there was a national security vulnerability in entrusting private industry with the responsibility to adequately respond to a surge in demand during wars. There were two main issues: capacity and capability. The belief was that industry, driven by profitability, would not maintain surge capacity, would not invest in the capitalization to be prepared in wartime, and would not have on hand adequate, capable personnel to sustain the war machine. Therefore, organic government depots were created to maintain this vital need.

Current Land Combat Systems (LCS) Maintenance Facilities

Anniston Army Depot (ANAD) Anniston, AL, overhauls and repairs heavy and light combat vehicles, artillery, and small arms. The depot has leased space to, and partnered with, General Dynamics Land Systems (GDLS) for M1 Abrams repair, Stryker resets and Fox upgrades. ANAD is also a subcontractor to BAE for the M88 Tracked Recovery Vehicle (TRV) and the M113 Fox, and has a partnership with Honeywell for the AGT Turbine Engine repair.

Letterkenny Army Depot [LEAD], Letterkenny, PA, is charged with mobile electric power systems, tactical missile repair, and High Mobility Multi-purpose Wheeled Vehicles (HMMWVs) and material handling equipment (7.5 ton cranes).

Red River Army Depot, Red River, TX, is primarily used for ammunition storage and associated quantity-distance safety zones, except for maintenance of Bradley Fighting Vehicles Series (BFVS), Multiple Launch Rocket Systems (MLRS), and some power train and generator/starter components. BRAC 2005 originally recommended closure of RRAD, but dropped the recommendation citing wartime activity disruption.

Marine Corp Logistics Base (MCLB) Albany, Albany, GA, the Marine's eastern location, provides maintenance, testing, and training for vehicles Assault Amphibious Vehicles (AAVs), Light Armored Vehicles (LAVs), HMMWVs, M88 TRVs, various trucks, Logistics Vehicles Systems (LVSS) – MK48s and trailers, M9 Armored Combat Earthmovers (ACEs), Armored Vehicle Launched Bridges (AVLBs), and Heavy Expanded Mobility Tactical Trucks (HEMMITs). The base also provides custom armor kits for HMMWVs, Medium Vehicle Tactical Replacements (MVTRs), and LAVs, repairs or remanufactures military ordnance, motor transport, engineering, general purpose, electronic, and communication equipment, and maintains power train components, starters, alternators, and generators.

MCLB Barstow, Barstow, CA is the Marine Corps' western location, and mirrors MCLB Albany. MCLB Barstow also provides a valued storage capability due to its arid location.

Though not a service designated maintenance depot, the Joint Systems Manufacturing Center, Lima OH, is a GOCO facility currently charged with depot maintenance of Abrams tanks and the Cougar vehicle. GDLS is only contractor operating on the facility at present.

There are two other Army designated maintenance depots, Corpus Christi Army Depot [CCAD], Corpus Christi TX, and Tobyhanna [TYAD] Army Depot, Tobyhanna PA. CCAD provides maintenance to fixed rotary aircraft, while TYAD performs maintenance of ground, airborne, navigational, and satellite communications/ electronics equipment and missile systems. Due to the nature of their missions, neither of these depots are included as part of the LCS maintenance depot community.

Depot Legislation and the Future of LCS Depots

Congress created protectionist legislation for depots; the most important of these is the 50/50 rule. Title 10 USC 2466, *Limitations on the Performance of Depot-level Maintenance of Materiel*, requires that no more than 50 percent of any fiscal year's depot maintenance funds may be expended for work done in the private sector (Steffes, 2003, p.41).

During the Cold War, depot maintenance capabilities and capacity continued to grow and funding levels remained high; after the Cold War, workloads decreased yet dollars expended increased over 72% (adjusted) from 1987 to 2002 (GAO, 2003, p.4). Army depots, in particular, were criticized: "work performed in Army depots declined by 36 percent from fiscal year (FY) 1987 through FY 2002, while their total depot programs grew" (GAO, 2003, p.4).

The pressure to downsize defense saw the birth of the BRAC Commission in early 1988. Army depots in particular were prime targets during BRAC 2005, but the surge in maintenance and repair caused by the Afghanistan and Iraq Wars provided protection from closure and major product reassignments.

There are several facilities that may be at particular risk. 1) The JSMC is not a designated maintenance repair facility, has significant recapitalization issues to overcome, and appears behind other facilities in efficiency improvement programs. On the other hand, the EFV and M1 production lines are powerful anchors for the facility's continued operation. 2) BRAC had planned to close RRAD, but the current war and the Bradley repair workload changed that plan. RRAD has yet to improve its market position so it is possible RRAD will again be scrutinized after current hostilities end. 3) LEAD has demonstrated excellent efficiency and flexibility in handling miscellaneous small product lines, but has not demonstrated competence and excellence in a major weapon system refurbishment. This gap may leave them vulnerable to BRAC's habit of finding one depot per product line. 4) MCLBs may be forced to increase maintenance at Army (or Joint) depots, thereby scaling back or closing one of its bases. USMC experts counter that the Corps requires both bases, to support the Atlantic and Pacific fleets.

Joint maintenance depots, like joint program offices may be a future economic consideration. For example, a geographic proximity, workload similarities between ANAD and MCLB Albany, and ANAD's reliance on Robins Air Logistics Center, Warner Robins GA, for much of its receiving/shipping, a joint future may become a serious consideration. Partnering, in its various forms, appears to be a wave of the future. The savings and efficiencies for both contractor and government are well documented; however the real selling point is the potential to address Congressional concerns of maintaining an organic capability, while promoting "best value" efficiencies agreeable to the DoD acquisition community.

Appendix 2—Combat Vehicle Modularity and Modernization

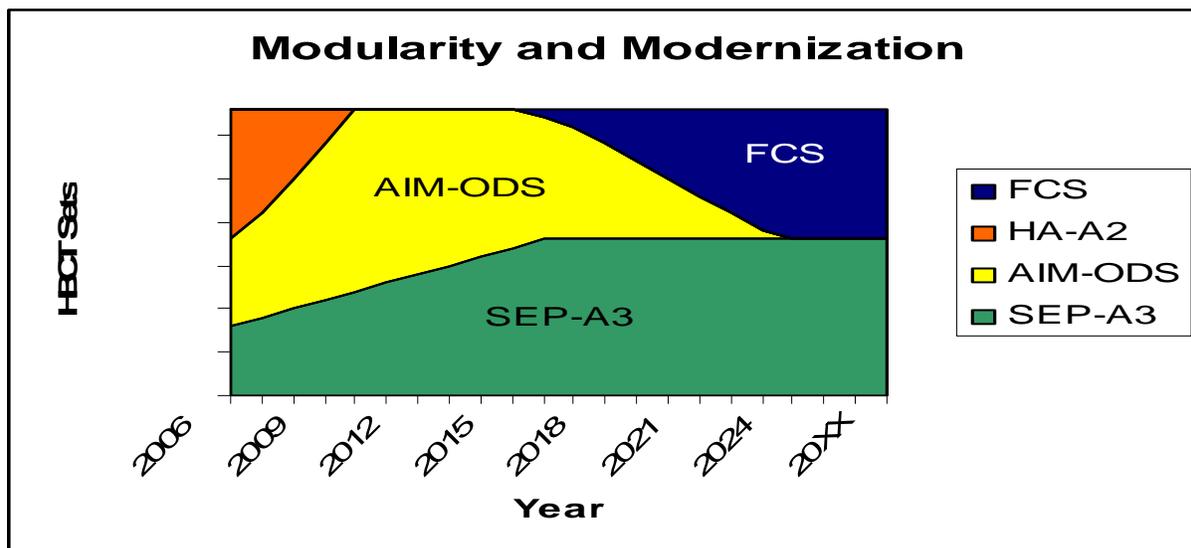


Chart created from a similar chart in Weapon System Review briefing by COL Larry Hollingsworth to the Army Staff, February 2006, slide 9.

AIM stands for “Abrams Integrated Management”. The AIM process takes place at Anniston Army Depot, where M1A1 and older model M1 tanks are completely refurbished and brought to the latest M1A1 AIM standard. The AIM standard evolves over time to deal with obsolescence and standardization issues. While this evolution does involve some system upgrades each year, they are generally not of such an extent as to greatly increase the AIM tank’s performance envelope. For this reason, the AIM process is almost exclusively O&M funded.

ODS stands for “Operation Desert Storm”, a configuration that bears improvements that were requested by soldiers after the 1991 Gulf War. The ODS standard has itself evolved over time, with latest ODS configuration including appliqué Future Battle Command Brigade and Below (FBCB2) computers.

SEP stands for “System Enhancement Program”. The SEP process begins with tanks being stripped down at Anniston Army Depot, and then shipped to the Lima Army Tank Plant for upgrade to the M1A2 SEP configuration. The upgrades include a hunter-killer sight system, advanced optics and sensors, and embedded command and control electronics. These are significant enhancements that greatly increase the tanks performance envelope. For this reason, Procurement funding is used for most of the SEP upgrade.

The M2A3 Bradleys have upgraded sensors, optics, navigation, and fire control systems. They are also equipped with integrated armor (as opposed to appliqué armor) and FBCB2. This upgrade requires extensive modification to the structure of the Bradley turret.

Appendix 3—Aberdeen Test Center

Aberdeen Test Center

The Aberdeen Test Center (ATC) is DoD's premier test facility for land combat systems testing and serves as the Army's Center of Excellence (COE) for direct live fire testing. ATC has limited range space, half of which lies in the Chesapeake Bay, and they are also somewhat constrained by environmental issues. ATC is currently operating on a wartime footing (3 shifts per day) and currently has a \$260M per year workload. In FY06 alone, ATC surpassed all but one of its benchmarks from the previous highest output year, FY92. ATC is seeing a similar trend in FY07. Funding is always a problem for ATC as only 80% of their overhead is funded by Congress. The remainder of funding is made up through testing based on "mission" funding. Specifically, when contractors test vehicles, ATC can charge overhead rates that are fair and allocable. ATC can also support civilian testing, and can use revenues for any designated purpose. This revenue helps bridge the gap in overhead funding that amounts to a 20% shortfall in annual appropriations. ATC utilizes a civilian/contractor mix and most of their labor is PM funded. Of note is the fact that the FY06 NDAA changed their accounting procedures, wherein DOD customers can no longer be charged for services. A concern from ATC is that this new direct appropriation process may acutely impact ATC once a normal peacetime budget is restored.

ATC has limited design and manufacturing capability and admits their role is for testing; however, to satisfy immediate theater requirements they developed and fielded the FRAG 5 Kit for the up-armored High Mobility Multi Purpose Wheeled Vehicle (HMMWV) program and are currently working on FRAG Kit 6. ATC admits the kits are likely to be outsourced to industry for manufacture; however, ATC fulfilled a critical immediate need because the acquisition system is less agile than demanded by the operational need. ATC has built such an excellent reputation for quality that private contractors frequently attempt to conduct limited testing on their equipment at ATC simply to advertise, "Tested at ATC". The obvious problem is that it is unclear what this designation means, especially since customers continue to migrate testing to less active facilities where they receive higher priority.

ATC is currently in the middle of testing for DoD's MRAP vehicle program. Over 36 vehicles were scheduled to come to ATC for accelerated testing in order to meet an ambitious projected delivery of November 2007. A glaring problem exists: ATC cannot test 36 vehicles at once. A better strategy would have been for DoD to space the MRAP delivery over an extended period of time. Some industry experts believe that MRAP will have automotive maintenance issues in theater due to the low amount of miles driven in formal testing (3,000).

Endnotes

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- ³⁷ AIM stands for "Abrams Integrated Management". The AIM process takes place at Anniston Army Depot, where M1A1 and older model M1 tanks are completely refurbished and brought to the latest M1A1 AIM standard. The AIM standard evolves over time to deal with obsolescence and standardization issues. While this evolution does involve some system upgrades each year, they are generally not of such an extent as to greatly increase the AIM tank's performance envelope. For this reason, the AIM process is almost exclusively O&M funded.
- ³⁸ SEP stands for "System Enhancement Program". The SEP process begins with tanks being stripped down at Anniston Army Depot, and then shipped to the Lima Army Tank Plant for upgrade to the M1A2 SEP configuration. The upgrades include a hunter-killer sight

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³⁹ ODS stands for “Operation Desert Storm”, a configuration that bears improvements that were requested by soldiers after the 1991 Gulf War. The ODS standard has itself evolved over time, with latest ODS configuration including appliqué Future Battle Command Brigade and Below (FBCB2) computers.

⁴⁰ The M2A3 Bradleys have upgraded sensors, optics, navigation, and fire control systems. They are also equipped with integrated armor (as opposed to appliqué armor) and FBCB2. This upgrade requires extensive modification to the structure of the Bradley turret.

⁴¹ Chart created from a similar chart in Weapon System Review briefing by COL Larry Hollingsworth to the Army Staff, February 2006, slide 9.

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⁴⁷ There are many other possibilities for consolidation of the industrial base. Possible outcomes include:

- RRAD closed and business moved to ANAD
- Barstow closed and LAV work moved to ANAD
- ANAD designated Center of Excellence for EFV
- BAE and GDLS co-operate in Lima; perhaps form a joint venture for production. Army/Marines might require GDLS and BAE to maintain separate R&D capabilities; they would then compete on development contracts but not production contracts. This idea may be controversial. One contractor interviewed prizes their proprietary manufacturing processes more than their design work. Also, production contracts are lucrative, making competition important to DoD to ensure costs are controlled.
- Army closes Lima and moves production facility to ANAD (still GDLS GOCO but at ANAD where presumably the operation could be “right-sized” and lower overhead costs achieved)