LAND COMBAT SYSTEMS

It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of light, it was the season of darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to heaven, we were all going direct the other way--in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only.

-- *A Tale of Two Cities* by Charles Dickens

ABSTRACT: During the 1990s, the U.S. Land Combat Systems (LCS) Industry went through a challenging period of consolidation as defense budgets declined and demand for ground combat equipment waned. Increasingly, joint ventures and partnerships have been formed between and among domestic and foreign LCS firms to maximize cash flow as well as share the risks and rewards of program development. In this regard, the U.S. Army's transformation vision is being closely watched as the worldwide LCS Industry seeks to capitalize on this potentially lucrative initiative. The vision requires that LCS firms become even more flexible and adaptable, but also forces them to fundamentally re-examine core capabilities. While "metal bending" knowledge is still important, the industry's future prime contractors will be lead systems integrators who are able to deal with increasingly complex platforms and systems-of-systems. One weakness of the vision creating some uncertainty in the industry has been airlift requirements for this transformed force, which still exceed projected capabilities and warrant clarification by the Department of Defense.

For the foreseeable future, the U.S. LCS Industry will be critical to meeting U.S. national security needs, necessitating continued close government stewardship. Dilemmas faced by such stewardship include deciding on the degree of foreign participation allowed by U.S. LCS firms and weighing LCS firms' implementation of lean manufacturing techniques, necessary for their economic viability, against the nation's need for surge production in the event of emergencies. Although the LCS Industry faces challenges in coming years, its opportunities for growth appear to remain significant.

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INTRODUCTION: With the end of the Cold War, worldwide government expenditures for land combat systems (LCS) declined. In the United States, reductions in military budgets led to sharp declines in the number of U.S. prime contractors building military platforms.[1] Fewer dollars and a reduced demand for their products led remaining contractors to consolidate facilities, eliminate personnel, reduce the number of suppliers, and attempt to improve production processes. This industrial base learned to be "lean" with low overhead costs and "just in time" inventory deliveries to maintain economic viability. Rapid surge and mobilization capabilities, however, suffered from this emphasis on cost-effectiveness.

Not only have new fiscal realities re-shaped the industry since the Cold War, but also the character of conflict has changed from a NATO-Warsaw Pact struggle involving heavy forces to regional ethno-political conflicts demanding lighter forces. The corresponding change in requirements is perhaps best suggested by the fact that the majority of legacy forces are too heavy for rapid insertion and, once on the ground, too heavy for the unimproved roads and bridges found in many areas of potential conflict. This change in operational requirements has caused the military customer to seek multi-functional LCS.

In 1999, the Army announced a priority program to transform itself into a rapidly deployable "Objective Force." To reach this goal, the Army envisions development of Future Combat Systems (FCS) based on technologies that will network forces to provide superior mobility, battle space awareness, enhanced lethality and survivability.

Until the fielding of FCS, however, the Army plans to retain the capacity to rebuild and upgrade older platforms including the Abrams tank and Bradley infantry-fighting vehicle. Recapitalization of this legacy force equipment, particularly tracked armor, will sustain the LCS Industry until FCS programs are further along.

Industry health and national security are inextricably linked. Industry provides the skills and facilities to research, develop, and manufacture land combat systems, while the nation requires cost-effective capabilities to implement security policies. The purpose of this study is to assess the health of the LCS Industry and its ability to support the U.S. national security strategy. It integrates course work, individual research, and visits to domestic and international LCS manufacturers to form conclusions about the industry's ability to meet the current national security strategy. Following each visit, seminar members compared their impressions, noting where industry and national defense policies were consistent and where they diverged. The study's objective is not to criticize either industry or government, but to understand where gaps between resources and policy exist.

THE INDUSTRY DEFINED: The land combat industry encompasses a variety of systems: tanks, infantry fighting vehicles, cannon and missile artillery, tactical trucks and robotics. The landscape of today's LCS Industry not only includes its products and services, but also its workforce, financial health, manufacturing standards, and surge capacity. A breakout by type of vehicle follows.

Tracked Armored Vehicles. Tracked vehicles are designed to operate in almost any terrain. General Dynamics Land Systems (GDLS) and United Defense Limited Partnership (UDLP) are the domestic prime contractors and system integrators for

tracked vehicles. Vehicles produced by these two companies include the M1 Abrams tank, M2/3 Bradley Fighting Vehicle, M109 self-propelled howitzer, M88 recovery vehicle, M9 Armored Combat Earthmover, M113 family of vehicles, Multiple Launch Rocket System, and Marine Corps Amphibious Assault Vehicle. Other systems under development include the Marine Corps Advanced Amphibious Assault Vehicle (AAAV).

Wheeled Armored Vehicles. Like tracked armored vehicles, wheeled armored vehicles are designed to operate in the harshest terrain. Lacking the heavy armor protection of tracked vehicles, wheeled vehicles are easier to transport, maintain, and logistically support. Wheeled vehicles can be armed with cannons (up through 105-millimeters), machine guns, and missile launchers. GDLS and General Motors Defense of Canada (GMD-C) produce the family of Light Armored Vehicles (LAV) III.

Tactical Wheeled Vehicles. In addition to transporting personnel and equipment, tactical wheeled vehicles serve as platforms for command, control, and communications as well as medium caliber weapons (up through 30-millimeters). Tactical wheeled vehicles must navigate the same terrain and distances as the combat forces that they support. Although the survivability requirements for tactical wheeled vehicles are usually less stringent than for armored vehicles, the need for off-road tactical mobility, reliability, and ease of maintenance remain fundamental in their design. Tactical wheeled vehicles fall into three main categories: light, medium, and heavy. Vehicles typical of these categories include the following:

a) The High-Mobility Multipurpose Wheeled Vehicle (HMMWV), the Commercial Utility Cargo Vehicle, and other trucks with less than 2 ½ tons cargo capacity are termed light wheeled vehicles.

b) The Army's Family of Medium Tactical Vehicles (FMTV) and the Marine Corps' Medium Tactical Vehicle Replacement (MTVR) with capacities between 2 ½ and 7 tons are classified as medium wheeled vehicles.

c) The Heavy Equipment Transporter (HET), Heavy Expanded Mobility Tactical Truck (HEMTT), and Marine Corps' Logistics Vehicle System (LVS), as well as other trucks with a capacity greater than 7 tons, are categorized as heavy tactical vehicles.

When considering these vehicle categories, however, it is important to note a further delineation within the U.S. military vehicle fleet. A vehicle may be a legacy system that eventually will be phased out, an interim force vehicle that may serve as a bridge to future systems, or a future force vehicle that may be deployed as part of the Army's "Objective Force." This delineation is necessary in order to fully appreciate the industry outlook since the Army, as the major customer for land combat systems, will be focusing its efforts and money on the FCS for the foreseeable future.

CURRENT CONDITIONS: This section of the industry report examines the LCS global markets and trends in the United States and Europe.

Global Markets

American weapons are desired in many foreign markets because of their demonstrated combat performance. America's dominance in the international arms marketplace may continue, despite strong European competition in some areas such as tanks, if the U.S. remains committed to modernizing its LCS command, control, intelligence, surveillance, and reconnaissance capabilities to increase battlefield

responsiveness, accuracy, and lethality. Future systems are planned to require less fuel, spare parts, and munitions. These innovations will benefit the United States both in conflict and in the international marketplace.[2] However, some observers argue that the possible increased costs of U.S. interim weapons and FCS may increase the attractiveness of weapons offered by European and other LCS producers.

Some argue that the search for competitive advantage among major international LCS-producing firms is reaching a crescendo. They assert that foreign manufacturers will only specialize in weapon systems where they excel. European LCS producers have done innovative work in fielding light vehicles designed to safeguard passengers from mine blasts and are offering these on international markets. As major international producers fall behind the United States in developing many high technology military weapons, they may narrow their concentration to less technologically sophisticated parts for U.S. systems. Even here, they may face a dwindling market as U.S. weapons become more technologically sophisticated. In any case, European LCS producers will continue to build weapons that are technologically inferior (by emerging U.S. standards) for their own use and for export to developing countries.

U. S. Industry Trends

Since the end of the Cold War, modernization funding constraints led to uncertainties in the size and pace of production programs. This is significant because the production phase of the weapon system acquisition cycle is where industry traditionally recoups past investments and obtains profits necessary for continued growth. In addition, the Defense Department significantly cut its number of "new start" programs. The defense budget decline triggered a series of defense industry consolidations that prompted a downsizing of capacity and people. Many suppliers left the market for other opportunities and, in some cases, went out of business entirely.[3]

During this same timeframe a 33 percent reduction in U.S. military personnel and corresponding decrease in equipment purchases caused the Army's requirements for vehicles to decline steadily. The number of U.S. producers of tactical wheeled vehicles decreased from six to three and for tracked combat vehicles decreased from three to two. This represents a significant decrease of LCS manufacturers in the U.S.[4] While these are major reductions in the industrial base, a lack of competition in the LCS Industry is not yet an issue. The issue is whether these LCS companies can rely on their core market, the U.S. government, for future business to maintain their viability. Without the stability an optimistic long-term outlook provides, capital markets will look elsewhere to invest their money. This limits the industry's financial flexibility and leads to less internal investment, the catalyst for next-generation development and innovation.

The U.S. LCS Industry initiated steps to counter these downturns. Many larger LCS companies purchased smaller ones to gain supply and manufacturing efficiencies. They created commercial product lines to supplement their defense business. They established and maintained partnerships with foreign companies to extend their global reach and stabilize cash flow. Some LCS firms have incurred heavy debt load as a result.

However, the near-term financial health of the LCS Industry, with the possible exception of UDLP, is on the positive side. For this trend to continue in the future, the LCS Industry must be flexible in the defense acquisition process and concentrate on innovation as it relates to the Army's "Transformation" goals. The Army is taking a

three-step approach in its efforts toward transformation. The approach is to recapitalize, modernize and sustain its legacy forces, provide an interim force capability that fills the gap between today's capabilities and those projected for the future, and at the same time develop the "Objective Force". This transformation will have long-term effects on the industrial base as a whole. The Army strategy could provide immediate opportunities for LCS producers, or more diverse and potentially greater future opportunities. There are major areas within each Army Transformation phase where the LCS Industry plays a role.

a) Legacy Upgrades: The U.S. Army's main battle tank will continue to be the M-1 Abrams for 25 or 30 years. To maintain its relevancy and ability to interface with the digitized force, the Army began the M1A2 System Enhancement Program (SEP) in 2001. With an initial $883 million contract awarded to GDLS, the Army began a multi-billion dollar modernization program that will continue through 2012. The May 2002 cancellation of the Crusader program, with an estimated cost in the billions, will affect UDLP's current role in the LCS Industry.

b) Interim Force: The Army's choice for its Interim Brigade Combat Team (IBCT) is the Interim Armored Vehicle (IAV). The requirement for an interim vehicle led to the award of a six-year, $4 billion contract to the GMD-C and GDLS joint venture. They will deliver 2,131 IAVs by 2008. The IAV is the Army's first new ground combat acquisition since the 1980 introduction of the Bradley infantry fighting vehicle. UDLP's loss of the IAV contract, combined with the cancellation of Crusader and the outcome of the FCS concept design, could severely limit its future role as an armored vehicle producer.

There is also a race for a multi-billion dollar contract to produce the next generation of trucks and trailers for the Army's FMTV. These vehicles will support both interim and "Objective Force" requirements. Stewart & Stevenson, the producer of the current generation of FMTV, and Oshkosh Trucks are competing for this lucrative near-term contract.[5] An award to Oshkosh could place Stewart & Stevenson's defense group in severe jeopardy.

c) Objective Force: FCS is the linchpin of the Army's transformation. By 2032, FCS will replace the current fleet of Abrams tanks, Bradley fighting vehicles and other armored vehicles. Planners wish to pursue that technology to provide the FCS the lethality of a 70-ton tank using a significantly lighter platform that is deployable in a C-130 aircraft. The debate over tracked versus wheeled (for armored vehicles) remains open. Although UDLP is concerned the move toward lighter vehicles will force them from the industry, others believe it will increase competition. As former Army Acquisition Chief, Mr. Paul Hoeper, stated, "As we get lighter, I think we'll have a more competitive industrial base…There are going to be more companies capable of building lighter vehicles than there are of building very heavy vehicles that we have bought in the past."[6]

European Industry Trends

Reduced defense budgets hurt the European LCS Industry, forcing them to cancel modernization efforts and extend timelines.[7] At the same time, they have lagged behind U.S. industry's efforts to consolidate and form regional partnerships. Although, in the past two or three years some national and international consolidation has begun. These

industry partnerships enable the pooling of resources and entry into foreign markets that safeguard economies of scale and provide financing for modernization. Their main source of cash flow and profitability is external sales. In addition, to maintain a steady cash flow and ensure profits during the modernization hiatus, the European LCS Industry is taking advantage of contractor logistics support (CLS) opportunities to increase revenues.

Despite the existence of the European Union, there appears to be no real over-arching European LCS Industry strategy. The LCS efforts appear fragmented and each country's national politics plays a major role in determining where R&D investments are made. With the reduced R&D budgets, European LCS capabilities and technologies are lagging behind those of the U.S. The interoperability required to operate in coalition with our allies is in jeopardy if this trend continues.

In a highly competitive 1990's arms market, European industries lost some markets to American, Russian, and Chinese competitors. The loss of potential markets hurt the ability of European defense industries to devote arms sales revenues to research and development.[8] European governments also faced a danger that by relaxing arms export controls, sales would increase to unstable nations along Europe's periphery and beyond. This policy could decrease rather than increase European security.[9] The relative loss of domestic and export LCS markets spurred the consolidation of some European defense industries.[10]

Other Regional Trends

Modernization difficulties experienced by other regional LCS producers surpass those encountered by the European LCS defense industry. Most of these LCS producers have suffered steady declines in domestic and export markets. While many arms companies ceased operation or curtailed weapons production, some successfully negotiated licensing and co-production arrangements with foreign arms manufacturers. Such partnerships enabled some countries to modernize their LCS Industry. India, Pakistan, Turkey, Egypt, Israel, South Africa and Brazil have continued their LCS production, sometimes under licensing and co-production agreements, while importing other needed weapons. Outside of Europe, few countries export combat vehicles. In 2000, military vehicle exporters included Russia, Ukraine, Czech Republic, Poland, Slovakia, China, Turkey, and Pakistan. Heavy emphasis remains to export retired or upgraded Soviet-era weaponry to such countries as Georgia, India, Iran, Peru, Sri Lanka, UAE, and Yemen, rather than producing new weapons for export. The notable exception is Russia's licensing deals with India and Iran.

In the Middle East, Egypt has the largest arms industry among the Arab states. Twenty-eight state-owned arms factories and test facilities produce weapons ranging from small caliber ammunition to tanks and aircraft. Some Egyptian weapons are of indigenous design, others reverse-engineered, while many others are produced under license or through co-production agreements. Egypt pursues these arrangements to enhance its technical capabilities. Their goal is to exercise a degree of self-reliance in producing and maintaining many weapons. Egypt occupies a prominent regional security role bringing stability to the Middle East. Among licensed and co-produced weapons, Egypt has built the "Walid" and "Fahd" 4x4 armored personnel carriers, which are based on German designs and parts. Egypt also manufactures the M1A1 Abrams Main Battle

Tank under a co-production arrangement with GDLS, the M88A2 Hercules armored recovery vehicle with UDLP, and the 635NL semi-trailer with Oshkosh. Egypt buttressed its defense capabilities by importing high-technology armaments, including U.S. patriot air defense missiles, the HMMWV from AM General, and the Oshkosh M978 HEMTT refueling/wrecker and the M1070 HET heavy equipment transporter.

CHALLENGES:

Of the many challenges facing the U.S. LCS Industry, three issues stand out. The first issue is the steady decline of the industrial base. The second is the industry's effort to incorporate world-class manufacturing standards and logistics support. A third issue is the consolidation and globalization of the supplier base and its impact on rapid potential mobilization.

The Industrial Base

The greatest threat to the LCS industrial base, especially the heavy tracked vehicles, is the perception these capabilities are no longer needed due to the end of the Cold War. Today, there is a more pressing requirement to develop the Army's FCS initiative. President Bush's proposed $2.13 trillion FY03 budget includes a 14 percent hike in military spending. Included in this proposal is $812 million to purchase 332 IAVs for the first IBCT and $707 million earmarked for FCS program development.[11] In addition, the Army reportedly cancelled 18 various programs to save $3.4 billion in FY 2003-2006. In May 2002, the Secretary of Defense cancelled the $11 billion Crusader program and on 21 May 2002 testified before Congress "…transformation investments cannot be made without terminating some programs and finding other savings."[12] The merits of each cancelled program are not in question, but the Army sacrificed these initiatives to accelerate the FCS development and deployment.[13] The Army's investment strategy reflects a clear paradigm shift from resourcing legacy capabilities to committing funds for the proposed FCS Objective Force.

In order to accommodate the accelerated pace of FCS development, the Army is maintaining a lukewarm production capability for armored vehicle modernization and refurbishment programs. At the same time, the Army expects to employ its 20 year old refurbished weapons platforms for an additional 25 to 30 years. The result is that some legacy system companies have only low volume contracts with modernization upgrades and furnishing critical parts as their salvation and bane at least until the new FCS requirements come about. This fosters a high stakes environment for armored land vehicle contractors. The award of the FCS contract could make or break one of these companies since the Army will likely invest most of its dollars in FCS development for decades to come. The LCS Industry no doubt will face considerable challenges with Army plans for the "Objective Force", but actions taken today can put them in a better position as viable competitors in the future.

Manufacturing and Logistics Standards

The LCS industrial base is at various stages of implementing "best business practices." These practices are imperative for them to remain solvent and competitive in the future marketplace. Their efforts encompass the following:

- International Organization for Standardization (ISO) certification of manufacturing processes and operations[14]
- Workforce retention initiatives
- Total quality management designed to reach six-sigma quality[15]
- Reduced production cycle time
- Lean manufacturing with reduced inventory
- Better supply management with fewer suppliers
- Use of long-term contracts with suppliers to leverage quality, service, and price
- Introduction of resource planning and web-based communications with customers and suppliers to boost efficiency

The revolution in military affairs and military force reductions is resulting in an initiative to take advantage of CLS. CLS can be considered "cradle to grave" support of a system and could include all three levels of maintenance (organizational, intermediate, and depot), provisioning, managing, distributing, or repairing system spares. CLS can effectively support depot teams, optimize low-surge workloads and replace consumables. Moreover, defense and commercial contractors can provide extensive support to maintain this military equipment and their expertise is critical to operational readiness. As a general rule, CLS should be considered an option if organic capabilities cannot be maintained at a reasonable cost or upon a demonstration of the potential for lower overall costs and/or increased readiness.[16] Opportunities for CLS must be reviewed to balance military needs and core competencies with efficiencies the government expects to gain through its use.

Supplier Base Globalization and Mobilization

As noted previously, fewer dollars and a reduced demand for their products prompted many LCS contractors to consolidate facilities, lower personnel strength, curb the number of suppliers and work to improve production processes. The industrial base learned to be lean by minimizing overhead and implementing "just in time" component supply and a reduced supplier base to remain economically solvent. Today's cost-effective lean manufacturing limits the industry's ability to surge. While we still have confidence in the industry's ability to surge, it will require more time to do so.

In the Annual Industrial Capabilities Report to Congress, researchers state that international borders are irrelevant to how businesses organize.

> Among the consequences of industrial consolidation and globalization are multinational companies with interlocking corporate directorates and production presence in multiple nations. Byproducts also include the possible loss of some

> domestic industrial capabilities, on both sides of the Atlantic, and an increasing degree of mutual defense dependence among the United States and its allies.[17]

Thus, the LCS Industry consolidation and globalization has created greater interdependence and vulnerability. The inability to access critical parts and resources will not only jeopardize production rates, it may undermine our national security posture. As such, a potential adversary could exploit any mobilization effort that depends on multinational suppliers.

OUTLOOK:

Near Term. The LCS Industry is fully capable of supporting near term national security requirements. If necessary, U.S. firms can enter into partnerships or joint ventures with European prime contractors. Intense competition for a limited number of contracts gives the customer excellent leverage to negotiate the best deal possible. However, there is the danger that a contracting number of suppliers could lead to monopolistic pricing. In the short-term between 2003 and 2007, the U.S. industry may find steady contract work for tracked armored vehicle upgrades and substantial contracts to produce wheeled, armored vehicles and tactical wheeled vehicles. European LCS Industries will likely rely heavily on external sales and joint ventures with other nations to maintain a steady cash flow.

Long Term. Regarding a long range forecast through 2022 and beyond, we predict a less volatile market for tactical wheeled vehicle manufacturers. The market for combat tracked and wheeled vehicles is less certain. Governments will continue to fund service life enhancement programs because they are more economical than buying an entirely new system. The domestic market for tracked vehicles may consist of new production contracts for the Marine Corps' AAAV and additional Abrams tank upgrades, especially the Guard and Reserves platforms. The future of the LCS Industry is tied to the Army's FCS. At this time, the impact of FCS on the industry is difficult to judge, since future land combat systems may not resemble today's equipment. Nevertheless, the LCS Industry remains excited about the concept. As one company executive stated, "the Army Chief of Staff has given renewed direction to a floundering industry." European LCS Industries may also become involved in U.S. or U.K. transformation initiatives.

GOVERNMENT: GOALS AND ROLE

The government is both a customer and innovator in the LCS Industry. As the customer, the government wants the best value, which does not always equate to the lowest price. The acquisition process focuses on achieving specific capabilities rather than prescribed military specifications. This shift in priorities led to changes in the relationship between the government and the contractor. No longer hostile adversaries disputing every dollar, both parties now focus on the overall success of a project. A more cooperative approach throughout the acquisition process led to improvements in system performance and greater customer satisfaction.

As an innovator, government encourages the industry to go beyond its preconceived notions of the possible. For instance, the Marine Corps' AAAV is a 39

short ton system that can achieve phenomenal mobility in the water and at the same time keep up with an Abrams tank on land. FCS innovation needs to go beyond design and engineering and incorporate product testing. With the accelerated pace of current procurements, product testing takes more of the total acquisition time before a new weapon is fielded. Processes to maximize testing efficiencies are the next challenge for military planners.

The Defense Department has long recognized that technology enables new warfighting concepts and offers opportunities to develop new capabilities. Through research and development (R&D) the nation will be able to provide the technology to maintain battlefield dominance and enhance the fighting capability of its ground forces. The government must ensure that it invests in R&D of emerging technologies that have direct application to required capabilities and can transition into ongoing programs.

Finally, the government must be careful that U.S. export policy does not become subservient to the short-term interests of foreign buyers and defense industries. It must remain focused on U.S. national security needs. While the LCS Industry remains a national asset, their participation in international arms sales should not place U.S. forces at risk while conducting operations throughout the entire spectrum of operations and conflict.

ESSAYS

Military Airlift and the Land Combat Systems Industry

The Army is in the midst of a transformation to make its forces light, lean and lethal. Although it will maintain its heavy armored force through 2032, the Army plans to field the IBCT. This organization will serve as the "bridge" between heavy armored unit and the Objective Force. The Objective Force is the centerpiece of the Army's transformation effort, and the instrument moving the Army forward is the FCS. To respond to a future crisis, the Army's interim brigade and Objective Force must have the ability to deploy rapidly anywhere in the world. This means airlift. It is the key enabler of the Army vision, however, the simple truth is the requirement outstrips the Air Force capability to provide airlift. Service and combatant commanders will continue to compete for limited airlift resources in the future, and this will provide a significant challenge for the Army to meet its documented deployment timelines. The Air Force is working to improve its airlift capability through a series of modernization programs, but the fact remains there is a significant gap between the requirement and capability. This gap is expected to increase over the next ten years.

Some military observers stress the importance of cooperation between the soldier and the airman to develop the "Objective Force". They believe the Army must consider airlift to ensure the effectiveness of the future land combat force. They recommend Army planners develop as a basic planning component a thorough understanding of the National Air Mobility System that establishes a foundation from which to build the "Objective Force". The argument is that this doesn't go far enough. To ensure capability and relevance for the Army's "Objective Force", the LCS Industry must also understand the nation's airlift capability and limitations. Airlift capabilities and limitations will

impact the industry's future in two major areas. The first area is industry's ability to design combat cell architectures for the Objective Force within the constraints of airlift.[18]

The ability to build an architecture that emphasizes rapid deployment while maintaining current capability is a daunting task. The Army insists all future combat systems weigh no more than 20 tons and fit inside a C-130 aircraft. Failure to achieve this basic requirement can have a significant impact on specific LCS procurements.[19]

A case in point is the $4 billion IAV program. GDLS and United Defense Industries each built prototype vehicles. The Army selected the GDLS product over the M8 Armored Gun System and the Mobile Tactical Vehicle Light designed by United Defense. The IAV will be produced in 10 variants to support infantry, fire support, reconnaissance and evacuation missions. After contract award, United Defense protested the Army's action arguing the service didn't properly consider IAV solicitation criteria or its own assessment of the competing proposals. In response, the Army indicated the advantages of the GDLS product in performance, to include its ability to deploy, offset the United Defense advantage in cost and schedule. In a 38-page report, the GAO supported the Army position and lifted the 4-month moratorium that initially halted IAV production.[20]

However, the GDLS/GMD-C vehicle is not without its problems. In a March 2002 article outlining the progress of IAV production, the interim brigade program manager indicated the Army is working with GDLS to ensure these vehicles meet the weight specifications.[21] Another consideration is the National Airlift Mobility System will have a bearing on future research of advanced combat vehicle technologies, such as light armor and laser weapons. Size and weight considerations will have a significant impact on the development and delivery of these new systems by industry.

The second area of concern is industry's role to establish a comprehensive logistics support concept for these weapons systems. The LCS Industry must thoroughly understand the airlift system and its limitations to formulate the logistics support plans and operations required by the Army. Under the Objective Force construct, Army doctrine calls for rapid and unpredictable movements to overwhelm an enemy force. The Army is reducing the logistics "footprint" of its maneuver forces. This places an increased reliance on airlift to provide "just-in-time" re-supply. The logistics support provided by these companies must optimize airlift efficiencies.

Today, military vehicle producers are establishing an integrated logistics support system to provide the Army with parts to maintain its vehicles. This initiative is evident with providers of tactical wheeled vehicles such as Oshkosh Trucks and Stewart & Stevenson. These firms must understand the national airlift system to ensure parts are delivered when and where needed. Industry has to recognize that the cargo throughput is restricted in a forward area, and this must be a consideration in their logistics planning process. The companies providing logistics support should make a concerted effort to develop parts containers that maximize the limited space on military cargo aircraft. The container must be durable and capable of rapid delivery to reduce the vulnerability of friendly forces. These firms should develop a logistics support system that enhances the throughput and efficiency of the airlift system. It just may be the difference in the outcome of a military action.

Airlift constraints influence the development of new land combat vehicles and technologies. If the vehicles fail to meet weight and size specifications, the Army won't

purchase them. This could affect the financial well being of individual companies within the LCS Industry. The dynamics of the airlift "pipeline" also influence the industry's ability to supply the deployed force. Industry must understand the intricacies of the airlift system to develop a sound logistics support capability that optimizes airlift throughput and reduces vulnerabilities to friendly forces during the delivery process. The recent selection of the Boeing/SAIC team as the lead systems integrator for the FCS offers a unique opportunity. Boeing's extensive experience producing large, commercial aircraft may be the catalyst to ensure the LCS Industry's understanding of the national airlift system.

A Snapshot of the Financial Health of the Land Combat Systems Industry

It's beyond the scope of this paper to assess the financial health of entire the LCS Industry. Accordingly, we will assess three companies representing a cross-section of the industry by taking a financial "snapshot" of their operations. These companies include: UDLP, Oshkosh Trucks, and Stewart & Stevenson.[22]

For the most part, all three LCS companies are on sound financial ground. Each company continues to turn a profit. The diversified customer base supporting Oshkosh and Stewart & Stevenson will ensure continued economic growth for both manufacturers despite DOD spending reductions. All are committed to efficient, lean manufacturing principles, rapid inventory turns and investment policies (including recapitalization, acquisition, and divestiture) aimed at improving their infrastructure.

In the near term, the Bush Administration's FY03 defense budget request augers well for the LCS Industry. For UDLP, the Defense Department set aside $472 million for the Crusader program, and $397 million was earmarked for Bradley infantry fighting vehicle sustainment.[23] Since that time the Defense Department cancelled the Crusader program, which may severely impact UDLP's current financial situation. Additionally, $347 million was approved for Oshkosh's MTVR production and $119 million for additional HEMTT vehicles. Stewart & Stevenson will receive $464 million for FMTV.[24] Currently, Oshkosh and Stewart & Stevenson are competing for the next generation of FMTV contract and it will be awarded in March 2003. The contract will pay in excess of $680 million in FY03. The entire program, estimated to run through 2020, will be worth over $17 billion.[25]

Besides profiting from future budget outlays, the LCS Industry draws financial strength from the very nature of its production capabilities. Citing the inherent liability of firms whose value derives more from conceptual than physical assets, Alan Greenspan had the relative value of the LCS Industry in mind when he said, "A physical asset … has the capability of producing goods even if the reputation of managers of such facilities falls under a cloud. Trust and reputation can vanish overnight – a factory cannot."[26]

Despite this bright picture, the LCS Industry has its share of financial issues. The primary sources of UDLP's cash flow, the Bradley and Crusader, consist of a legacy program and a system that is now cancelled. Heavily dependant on Congressional year-to-year appropriations, UDLP lacks a consistent funding stream. Their efforts to invest, re-tool, and plan are therefore constrained, while losses incurred by their failed IAV bid and the cancellation of Crusader could prove financially devastating. If they're unable to muster finances necessary to reduce leverage ratios, UDLP may become a defense sub-contractor or a firm ripe for acquisition.[27]

Although the diversified product lines of Oshkosh and Stewart & Stevenson contribute to each company's fiscal security, uncertainties lie ahead for both firms. Quite a bit is riding on the award of the next FMTV contract. Although it's unlikely either company will shut down if it doesn't win the bid, it will be a severe blow and impact the loser's ability to sustain financial growth without some sort of restructuring.

The LCS Industry also faces a challenge applicable to all defense contractors – cash flow. To successfully bid on a future contract, companies must invest "up-front" capital for R&D and assembly line re-tooling. If selected, contract money flows in, debts are covered and profits produce additional investment funds for the next bid. However, if a company isn't selected, investment debts must be covered with cash that otherwise would have been spent on the next contract competition. A recent ICAF briefer noted that investors not only value growth and earnings, but cash flow, especially since earnings and cash flow often move in tandem. By this logic, investors won't provide further cash relief unless businesses win contracts.

Diversification helps Oshkosh and Stewart & Stevenson maintain their cash flow and keep their leverage ratios in check, but UDLP's debt ratios are less than ideal, a current problem for heavy vehicle manufacturers.[28] While diversity is a wonderful "out" from the uncertainties associated with a single-source of cash flow, it's not always possible for defense contractors to branch out into the commercial market. Diversified or not, there isn't an LCS company in existence that can withstand repeated failure while pursuing defense contracts. To complicate matters, current competition is characterized by having fewer contracts, smaller production numbers, and longer time periods between contract awards. This places extreme pressure on a company to win the bid. As tactical systems development costs increase and programs are stretched out, companies still require financial stability, an adequate R&D base and the ability to support a program through its service life. Ultimately, it's critical these companies carefully develop their business strategies and invest wisely to receive revenues that will allow them to compete down the road. Indeed, how the LCS Industry handles this risk will decide its collective financial future.

Information Technology and the Land Combat Systems Industry

The Land Combat System Industry faces significant challenges as it begins to fully embrace the Information Technology (IT) age. Combat vehicles are changing from a system operated independently to a vehicle designed, built and operated as a networked system of systems. This change is primarily due to the increasingly complex requirements of the 21st century battlefield and enabled by increased IT capabilities. The challenge will be mastering the skills necessary to effectively integrate and produce these new capabilities.

Historically, combat vehicles typically operated often in large formations communicating by radio or hand signals. Navigation and shooting were done by physically sighting the terrain and targets. Today, battlefield commanders demand land combat systems that, with their traditional functions, are storehouses of knowledge. They must provide the crew with real time information on enemy and friendly unit dispositions. They must also be capable of operating independently and avoid detection through dispersion and digital communications

Combat vehicles are the next level of IT integration, but they operate in a demanding environment. Vehicles possess harsh shock and vibration patterns, limited power and space, digital communications equipment, and generally uncontrollable environmental factors. To successfully integrate IT capabilities into combat vehicles, the LCS Industry must gain additional expertise in software, hardware, electronic communications, precise electric power, digital transmissions and IT system integration.

Well versed in mature technologies, traditional manufacturers of combat vehicles must avoid becoming irrelevant, a lesson learned during WW II, where companies that couldn't incorporate new technologies were relegated to a minor role. An industry executive remarked that this situation places combat vehicle manufacturers in a difficult position, especially with IT integration. With the Army's plan for the legacy force, the potential LCS workload may be shrinking, precluding many companies from investing in additional infrastructure.

The LCS Industry must overcome several challenges to develop and produce more sophisticated vehicles by determining IT requirements and interpreting IT interoperability standards. The LCS Industry is poised to produce sophisticated vehicles for the military today, once requirements are clear. For example, today's specialty trucks, using a digital backbone to control the onboard systems, can determine the maintenance status for many of their components. This capability can determine if an engine needs repairs, what parts need to be replaced, or whether a system should be overhauled. The vehicle can then send this information to a maintenance facility to describe the condition of major sub-systems, alert mechanics, and even place a part order automatically. This initiative saves repair costs and improves vehicle readiness.

Comprised of a complex assembly of subsystems, combat vehicles are extremely expensive to produce, difficult to change, require long manufacturing lead times, and most important, must be near full development to test. Conversely, the IT industry develops and produces both software and hardware within months, and is capable of making changes literally overnight. This capability supports the Defense Department's call for increased use of 'spiral' development. With this acquisition model, products are prototyped with existing and near term technology, and then rapidly fielded. Seeking user feedback, improvements are made and then an updated system is fielded. This process is similar to a Microsoft release of a new Windows software baseline every few years while providing interim upgrades.

LCS contractors must be able to achieve interoperability with all IT systems on the platform, including Government Furnished Equipment. In 1999, senior Defense Department officials determined that major Information Systems under their review must have a key performance parameter covering interoperability. Because this requirement is poorly defined, several industry officials believe the current metric, the 'Joint Technical Standard,' is too vague to be of use. Combat vehicle companies must sort through the requirements process and determine what government assistance is needed to support the contractors' IT integration effort.

When looking ahead, the wave of future combat vehicle development can be seen in the FCS program. Because the Army now considers most traditional combat vehicles as legacy systems, their future is generally limited to system upgrades. Their replacements must come from the FCS program, which will clearly be a sophisticated IT system. The Army selected its industry team for the initial acquisition phase in March

2002. The capabilities of the FCS Phase I winning team are highlighted in their March 2002 press statement. The edited portions (*italics added*) are below:

> Both The Boeing Company and Science Applications International Corporation (SAIC) are a team with *experience in large-scale integration, communications, and combat systems.*
>
> ….
>
> Phantom Works and the Space and Communications business unit jointly lead the effort for Boeing. They are *leveraging the company's large-scale systems integration experience on programs such as the Apache helicopter, Ground-Based Missile Defense, and the International Space Station* into their concept. As the *world's largest space and communications company* the Boeing Company, S&C provides *integrated solutions in missile defense, information and communications*, launch services, and human space flight and exploration. It is a leading provider of space-based communications; the primary systems integrator for U.S. missile defense; a leading provider of intelligence, surveillance and reconnaissance; and NASA's largest contractor. SAIC is the nation's largest employee-owned research and engineering company, *providing information technology, systems integration and eBusiness products and services* to commercial and government customers.[29]

From the above statement, you can conclude that this team, clearly at the forefront of IT, represents the future of combat vehicle contractors. To be successful, it must be funded, staffed and supported so that it may effectively integrate a wide range of IT technologies into this system of systems.

Research and Development and the Land Combat Systems Industry

There are significant R&D initiatives by government, industry and academia to make the 21st century land combat systems more deployable, versatile, survivable, sustainable, agile, lethal and responsive. The emphasis is on fuels, safety, air deployability, crew station automation, target acquisition, advanced mobility, hit avoidance, and composite materials applications.

Fuel efficiency will be achieved through advanced diesel hybrids, fuel cells, cleaner fuels, and more efficient engines. Deployability and overall vehicle efficiency will be improved by increasing drive train efficiency and reducing aerodynamic drag, rolling resistance, and weight. Improvements in human-environment, human hardware and hardware-environment interfaces will contribute to the safety of the vehicle. Investment in vehicle electronics and IT is improving diagnostics and command & control capabilities**.** Environmental protection includes reducing nitrogen oxides, particulate matter, carbon monoxide and hydrocarbons.

Research on composite materials and hybrid vehicle construction promises to increase structural integrity and reduce the weight of vehicles. New armaments are being developed, including ballistic missile and active protection technology, to meet new threats. Rubber band track and wheeled designs are being pursued to improve the performance and speed of combat vehicles. Because of cramped conditions caused by added electronics and sensors, crew stations are being ergonomically redesigned. As the complexity of these vehicles increases, embedded training for the crews in a stand-alone and network environment is being pursued. Electric drive technology promises to increase fuel efficiency and reduce a vehicle's sound signature**.** The use of robots in FCS

requires high levels of onboard intelligence and perception capabilities, sensor technologies, communication and navigation systems that must operate in all environments.

Government-industry R&D initiatives include the National Automotive Center (NAC) at the Tank-automotive & Armaments Command (TACOM). The NAC, along with its partners Viridian-Engineering, AM General Corporation, Daimler Chrysler, AG, and Ford Motor Company, have adapted a modified commercial pick-up truck to perform some the missions now assigned to the HMMWV. They have revamped the Dodge 2500/3500 and Ford F-350 to improve their off-road mobility and payload capacity. NAC and Oakland University's Product Development and Manufacturing Center (PDMC) along with industry partners Daimler Chrysler, Eaton, Lear, Arvin Meritor, Compaq, and TRW Automotive are developing a "dual-use" electrical architecture system for both military and commercial vehicles. Project goals are to create a vehicle electrical architecture system that will realize greater functionality, reduced warranty costs, and reduction in R&D costs.[30]

IMPACT is an industry-academia cooperative program involving Ford Motor Company, American Iron and Steel Institute, the University of Louisville and Mississippi State University. The focus of the program is to design, incorporate and validate fuel-efficient lightweight technologies and identify and optimize vehicle attributes that increase capability for dual-use performance. A program with Integrated Concepts & Research Corporation, MSX International, and others provides the Army a vehicle platform to test, integrate and showcase cutting-edge automotive technologies. This project allows the Army to insert the latest in wireless communications, situational awareness and soldier safety technologies into its tactical wheeled vehicles. DARPA in partnership with Georgia Tech's Tactical Mobile Robotics (TMR) Program is developing a wide range of mission specification capabilities for the urban warfighter.[31]

Both Stewart & Stevenson and Oshkosh Trucks have made significant investments in R&D to improve the performance of their vehicles. Stewart & Stevenson is using computer simulations and analysis in the rapid development and trial of concepts without costly delays and expense of building and testing prototype hardware. Oshkosh Trucks has been working on hybrid electric-drive technology for several years, in cooperation with Rockwell Automation and other industrial partners. The technology can increase fuel economy by up to 40 percent over conventional power trains. It will also increase readiness, direct wheel torque control and increased on-board power and diagnostic capability.

UDLP is at the forefront in developing advanced gun technologies by teaming with other world leaders in projectile development and advanced propellants. This work has been focused around two sets of technologies: electro-thermal-chemical (ETC) guns and electromagnetic (EM) guns.[32] UDLP is also developing thick walled, complex composites for armored vehicles structures and have integrated into combat systems many key automation and robotic technologies necessary for the autonomous operations desired of future systems. GDLS is in charge of the AAAV and IAV programs that have incorporated improvements in armor, electronics, propulsion, and robotics features. Hit Avoidance technologies will require inclusion of sensors, countermeasures, and active defenses against both top attack and horizontal threats.

In summary, DOD's R&D investment in LCS is essential to force modernization. The FY03 defense budget has increased basic funding for R&D that will greatly benefit the industry. Greater reliance on commercial technologies and international partnerships can increase the pace at which improvements are incorporated into defense systems. It can also reduce the cost of those systems by applying the same competitive pressures and market-driven efficiencies that lead to accelerated development of technologies and savings in the private sector. If successful, dual-use technologies and capabilities can be developed to fulfill military mission needs, while the government takes advantage of reduced overall design, development, logistics and production costs. The challenge now is the integration of R&D efforts into existing and future systems.

CONCLUSION

In the face of declining defense budgets in the 1990s, the LCS Industry has undergone a shakeout, with some firms combining and others ending their production of LCS. The Defense Department has largely preferred to let market forces work in this industry, nevertheless its remaining depots and GOCOs act as a hedge against the loss of manufacturing and servicing expertise. Many surviving LCS industries have attempted to cut costs by adopting just-in-time supplier relations or by diversifying and stressing commercial applications. Declining acquisition budgets, combined with the aging of legacy LCS, have driven firms to emphasize life cycle maintenance and other contractor logistics support as additional revenue sources. Another industry trend has involved the formation of partnerships or joint ventures with foreign LCS firms to gain access to foreign markets and technologies.

In addition, as LCS systems become more complex the integration capabilities required of the Industry have come to the fore. To play a "prime" role, they must become lead system integrators, able to blend information technologies with traditional and advanced manufacturing processes at both the platform and system-of-systems levels.

As the military has faced declining budgets and personnel strength, privatization measures have raised the issue of what are military core competencies in fielding and maintaining LCS. Recently increasing defense budgets have included support for upgrading and recapitalizing legacy systems and enhanced R&D for developing interim systems, and planning for FCS. As the Army contemplates moving to FCS, the issue of how long it must maintain legacy land combat systems has come to the fore. If FCS is deployed by the end of the decade, as planned, legacy systems may be more quickly phased out. Even so, planning calls for the Abrams M1A to remain in the active inventory for another thirty years, meaning that in the foreseeable future, fielded LCS may include a mix of legacy, interim, and FCS weaponry. As the LCS transformation proceeds, however, the problem of interoperability with allied states' weaponry may worsen, particularly if allies continue to devote minimal R&D resources to the development of more technologically advanced land combat systems.

The European LCS Industry has faced many of the post-Cold War problems of the U.S. industry, including overcapacity, reduced domestic demand, and increased competition for contracts. European industry has been slower to adapt to these conditions, relying more on foreign sales to bolster their cash flow and profitability. These exports bolster their relatively small production rates, compared to those of U.S.

firms. European governments have been loathe to give up national self-reliance in producing LCS, though within the past two to three years this attitude has softened and some trans-national as well as intra-national industry consolidation has begun. So far, partnerships between U.S. and European LCS firms have been uncommon, with each side viewing the other as uncooperative. However, the United Kingdom's concept of Future Rapid Effects Systems (FRES), though less technologically aggressive, has parallels to FCS and may open the door to some cooperative U.S.-U.K. R & D arrangements. Issues that Defense Department continues to consider include whether such arrangements might create an unacceptable risk that the United States would be unable to access the capabilities, services, or products that it needs when it needs them or whether national security might be compromised by permitting access to U.S. capabilities, services, or products.

Finally, the seminar comes away with the belief that LCS remains as critical to National Security as ever. While the LCS Industry may not be in the heyday of the Reagan buildup, it is not the "worst of times." Opportunities continue to present themselves and those companies willing to go beyond what they've become accustomed to and make the investments necessary to remain competitive will thrive.

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