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ARMY COMBAT VEHICLES

Industrial Base Study's Approach Met Research Standards

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Why GAO Did This Study

As the Army reduces its number of troops, it requires fewer new ground combat vehicles, such as the Abrams tank and Bradley Fighting Vehicle. In response to questions raised about the effect of this planned decrease, the Senate Armed Services Committee and conferees for the National Defense Authorization Act for Fiscal Year 2013 directed the Army to conduct a study to examine the viability of its combat vehicle industrial base. The Army issued a contract with a management consulting firm to conduct the study, which was presented to congressional defense committees in April 2014.

The Joint Explanatory Statement to Accompany the National Defense Authorization Act for Fiscal Year 2014 included a general provision for GAO to assess the reasonableness of the Army study's methods. GAO examined the study's design, execution, and presentation of the results. This examination included, among other things, a review of the study's assumptions and the steps taken to ensure the validity and reliability of the study's data. GAO reviewed study documentation, briefings, and the final report to congressional defense committees and assessed its reasonableness using generally accepted research standards. GAO also interviewed Army officials, the study's authors, the two combat vehicle industrial base original equipment manufacturers, and several suppliers selected based on their perceived criticality to the combat vehicle industrial base.

GAO is not making any recommendations in this report.

View [GAO-15-548](#). For more information, contact Marie A. Mak at (202) 512-4841 or makm@gao.gov.

ARMY COMBAT VEHICLES

Industrial Base Study's Approach Met Research Standards

What GAO Found

GAO's review of the Army's combat vehicle industrial base study found that the study's methods—its design, execution, and presentation of results—were executed in accordance with generally accepted research standards, and, as a result, the study's key findings were reasonable and well supported. The Army's study found, among other things, excess capacity in the combat vehicle industrial base and a small number of at-risk critical suppliers. According to the research standards, a study's design should include, for example, establishing the objectives, scope, and methodology, and identifying study assumptions. Successful execution involves ensuring that the methodology was carried out as planned, or adjusted as appropriate to the evidence, and ensuring that data used in the study are sufficiently valid and reliable for the study's purposes. Presentation includes clearly documenting the study's results in a way that is relevant to stakeholders.

- First, GAO assessed the study's design and determined that it was sound. The study's objective (to assess the combined commercial and government combat vehicle industrial base and develop viable strategic alternatives to sustain that base within a constrained fiscal environment) addressed congressional direction. The scope was comprehensively designed to achieve the study's objective, and its methodology addressed the study's objective. The study's assumptions were generally reasonable, although some key assumptions could have been more explicitly stated. For instance, the study could have more explicitly stated that it viewed the consequences of changes to the industrial base from the perspective of the Army rather than, for example, from the perspective of manufacturers or individual suppliers.
- Second, GAO found that during execution, various limitations arose, which were generally identified and the study's authors took reasonable steps to mitigate. Additionally, the Army took sufficient actions to ensure the data used were valid and reliable for the study's purposes, such as obtaining data directly from the individual programs, then returning to these sources to ensure the data were being used appropriately.
- Finally, the study's findings were presented in a clear, comprehensive, and timely manner, with the analysis and findings going beyond the elements required by congressional direction. For example, the study's findings went beyond an assessment of the Bradley Fighting Vehicle and the Abrams tank to include a more holistic look at the vehicles and facilities in the combat vehicle industrial base.

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Abbreviations

ACV	Amphibious Combat Vehicle
AMPV	Armored Multi-Purpose Vehicle
BAE	BAE Systems, Inc.
DOD	Department of Defense
GDLS	General Dynamics Land Systems

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June 16, 2015

Congressional Committees

Ground combat vehicles provide an essential role in combat operations for the U.S. military by providing mobility, protection, and firepower on the battlefield. As the Army reduces its number of troops, there are fewer requirements to continue producing these vehicles.¹ The Army's budget request for these vehicles decreased from \$8.8 billion in 2010 to \$1.7 billion in 2013—the most recent year for which this information is available. Further, the Army anticipates more decreases in the production of combat vehicles between 2015 and 2019.

In response to questions raised over the effect of this planned decrease in production, the Senate Armed Services Committee and conferees for the National Defense Authorization Act for Fiscal Year 2013 directed the Army to report on the status of the combat vehicle industrial base.² In October 2012, the Army issued a contract with A.T. Kearney, a private independent management consulting firm, to complete an assessment of the combined commercial and government combat vehicle industrial base that supports the United States Army and delivered the final report to the congressional defense committees in April 2014. The Joint Explanatory

¹For the purposes of this report, we use the terms “producing” and “production” to include not only the production of new ground combat vehicles, but the improvement of existing combat vehicles through a variety of processes such as updating, remanufacturing, or refurbishing.

²Specifically, Senate Report 112-173 that accompanied a bill for the National Defense Authorization Act for Fiscal Year 2013 directed the Secretary of the Army to report on the Army's analysis and plans to utilize and configure its government-owned/contractor-operated facility, where Abrams tanks are produced, to efficiently and effectively meet the Army's tank and other tracked and wheeled vehicle production related requirements to meet capability goals to 2025 and beyond. The conference report accompanying the National Defense Authorization Act for Fiscal Year 2013 also directed the Secretary of the Army to submit a report to the congressional defense committees on the Bradley Fighting Vehicle industrial base, to include, but not be limited to, an assessment of the financial impact and risk of a production break for the Bradley Fighting Vehicle, including the cost of shutdown compared to the cost of continued production; and an assessment of the industrial capability and capacity impact and risk of a production break for the Bradley Fighting Vehicle, including the loss of a specialized workforce and supplier base. S. Rep. No. 112-173, at 23-24 (2012); H.R. Rep. No. 112-705, at 885 (2012) (Conf. Rep.).

Statement to Accompany the National Defense Authorization Act for Fiscal Year 2014 included a general provision for GAO to assess the Army's study, and report to the congressional defense committees on the reasonableness of the study's methods.³ We examined the study's design, execution, and presentation of the results to determine the reasonableness of its approach. This examination included, among other things, a review of the study's assumptions and the steps taken to ensure the validity and reliability of the study's data.

To determine the extent to which the Army study's approach was reasonable, we gathered evidence to assess the study, including interim and final study briefings, backup slides that detail the methodological elements of the study, and the final report to the congressional defense committees. To guide our assessment of the study, we identified generally accepted research standards for the design, execution, and presentation of findings that define a sound and complete study (see appendix I). Two GAO analysts individually evaluated the Army study against these standards, consulting with GAO specialists in the areas of economics, survey and research methods, and, as needed, obtaining clarifications and additional information from the Army and the study's authors. After completing their independent analyses, we compared the two sets of observations and discussed and reconciled any differences. We interviewed the study's authors to develop an in-depth understanding of the scope, methodology, limitations, data sources, and data validity and reliability steps taken as a part of the study. We also held discussions with Army officials from the Program Executive Office for Ground Combat Systems, which is responsible for providing ground combat equipment, including combat vehicles, to the warfighter, about the study scope and methodology, the data provided to the study's authors, and the steps taken to ensure the data was sufficiently valid and reliable for the study's purposes. To develop an understanding of their knowledge and perspectives on the Army study, as well as their perspectives on the combat vehicle industry more broadly, we met with officials from several Department of Defense (DOD) entities, such as the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy. To obtain a better understanding of the ground combat vehicle industrial base, we visited the three government and commercial facilities

³Joint Explanatory Statement to Accompany the National Defense Authorization Act for Fiscal Year 2014, 159 Cong. Rec. H7894, H7897 (Dec. 12, 2013).

that comprise the primary facilities for the production and maintenance activities for ground combat vehicles, and interviewed knowledgeable government officials as well as representatives from the two original equipment manufacturers, BAE Systems, Inc. (BAE) and General Dynamics Land Systems (GDLS). We also interviewed the original equipment manufacturer representatives, as well as representatives from six suppliers that participated in the study, to obtain their perspectives on the study. We selected the suppliers with a goal of obtaining suppliers that represented a mix of items produced for the combat vehicles and with consideration of the suppliers' perceived criticality to the combat vehicle industrial base. The views of these suppliers cannot be generalized to the views of all those suppliers that participated in the study. Additional details regarding our scope and methodology can be found in appendix II.

We conducted this performance audit from July 2014 through June 2015 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit and obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The Army's ground-based military operations generally use two kinds of vehicles: combat vehicles designed for a specific fighting function and tactical vehicles designed primarily for multipurpose support functions. Most combat vehicles move on tracks—including the Abrams tank and the Bradley Fighting Vehicle—but some move on wheels, such as the Stryker. See figure 1 below for the ground combat vehicles that were included as a part of the Army industrial base study.

Figure 1: Ground Combat Vehicles



Abrams Main Battle Tank
Quantity: 2402
Manufacturer: GDLS

Equipped with 120 millimeter main gun. Abrams tanks are tracked with special armor, 1500 horsepower turbine engine. Provides soldiers with the mobility, firepower, and shock effect to close in and destroy enemy forces.



Bradley Family of Vehicles
Quantity: 4,042
Manufacturer: BAE

Equipped with a 25 millimeter gun and/or missile launch capability. The Bradley is an armored and tracked vehicle that provides mobile protected transport of infantry to critical points on the battlefield and performs cavalry scout and other essential missions.



Stryker Family of Vehicles
Quantity: 4,466
Manufacturer: GDLS

Equipped with eight wheels. Provides combat support with ten variants and mission-dependent configurations that supports a variety of armaments, including a .50 caliber machine gun.



M109 Paladin Family of Vehicles
Quantity: 558 self-propelled howitzers and 521 tracked ammunition carriers.
Manufacturer: BAE

Equipped with a 155 millimeter cannon, the Paladin is a tracked, aluminum armored, self-propelled howitzer designed to destroy, neutralize, or suppress the enemy by indirect fire. Also includes a tracked ammunition carrier that provides operational support to the howitzer.



M88 Hercules
Quantity: 1,170
Manufacturer: BAE

Equipped with a boom, which enables a 35 ton lift capability, and a .50 caliber machine gun, the Hercules is an armored, tracked, recovery vehicle.



M113 Armored Personnel Carrier
Quantity: 5,218
Manufacturer: BAE

Equipped with a .50 caliber machine gun. Provides a mobile, survivable and reliable tracked-vehicle platform that, with upgrades, is able to keep pace with Abrams and Bradley equipped units.



Ground Combat Vehicle
Quantity: Not applicable
Manufacturer: Not applicable

Cancelled program that was previously expected to be the Army's replacement for the Bradley infantry fighting vehicle.



Armored Multi-Purpose Vehicle
Quantity: 2,897
Manufacturer: To be determined

Expected to replace the M113 in five mission roles: general purpose, medical evacuation, medical treatment, mortar carrier, and mission command. Currently in development.

U.S. Marine Corps combat vehicles^a

Includes the terminated Expeditionary Fighting Vehicle and, its potential successor, the Amphibious Combat Vehicle which is still in development and intended to transport Marines, including ship to shore operations, to secure a beachhead.



Expeditionary Fighting Vehicle
Quantity: Not applicable
Manufacturer: Not applicable



Amphibious Combat Vehicle
Quantity: To be determined
Manufacturer: To be determined

Source: GAO analysis of Army study documentation, Army program information, and information from past GAO reports; U.S. Army (photos). | GAO-15-548

^aUnited States Marine Corps' vehicles, such as the Amphibious Combat Vehicle, were also included in the Army study however the primary focus was on Army combat vehicles.

The combat vehicle industrial base is comprised of many separate but interrelated facilities in both the government and commercial sectors. The Army produces its fleet of ground combat vehicles using a combination of these facilities. The government facilities include the Anniston Army Depot in Anniston, Alabama, which overhauls the Abrams tank and Paladin vehicles, among other combat vehicles; and the Joint Systems Manufacturing Center in Lima, Ohio, a government-owned contractor-operated facility (operated by GDLS) which produces Abrams tanks and Strykers, among other combat vehicles.⁴ The BAE facility in York, Pennsylvania produces Bradley and M88 recovery vehicles, among other vehicles. In addition to the government and commercial production facilities, the combat vehicle industrial base also includes hundreds of suppliers who furnish parts and equipment to the combat vehicle original equipment manufacturers.

DOD officials, including those from the Army's Program Executive Office for Ground Combat Systems and others, such as the original equipment manufacturers, have expressed concern that the decreasing demand for ground combat vehicles and the corresponding impact on the industrial base could result in the inability to sustain the combat vehicle industrial base. Specifically, these officials indicated that decreased production of combat vehicles could lead to the loss of critical skills, production infrastructure, and key suppliers. Further, in the Army's 2011 Industrial Base Baseline Assessment, it indicates that these potentially negative effects could, in turn, negatively affect the military's ability to quickly restart production of parts and vehicles for future combat operations.

In response to questions raised over the impact of the planned decrease on the combat vehicle industrial base, the conferees to the National Defense Authorization Act for Fiscal Year 2013 directed the Army to conduct a study to examine the status of the combat vehicle industrial base, particularly in relation to the Bradley Fighting Vehicle, and the Senate Armed Services Committee directed the Army to report on its government-owned/contractor-operated tank production facility, which is where Abrams tanks are produced. The Army subsequently entered into a contract with A.T. Kearney, a management consulting firm, to conduct a

⁴Army depots provide maintenance activities to support combat readiness by providing services necessary to keep Army units operating worldwide. There are five Army depots nationwide, and the Anniston, Alabama depot is the one that, generally speaking, provides maintenance activities related to ground combat vehicles.

comprehensive study of the industrial base to address this congressional direction,⁵ as well as to provide visibility and knowledge to inform decision makers and senior leadership.

The key findings of the Army's study included:

- There is excess capacity in facilities with the ability to machine large, complex metal structures for the ground combat vehicle industrial base;
- Unique capabilities exist at each production and sustainment facility within the combat vehicle industrial base, but there is a significant overlap of similar capabilities across the facilities;
- A small number of skills such as armor steel welding are critical to the production and sustainment of combat vehicles;
- There are a small number of high risk critical and fragile suppliers, such as those that provide certain engines and transmissions, and the risk to these suppliers can be mitigated by individual company action or limited Army intervention;
- Production and sustainment demand is the factor that has the most impact on the industrial base; and
- There is a lower financial impact to the Army for potential production breaks—specifically, stopping all Bradley Fighting Vehicle production work at a particular facility—than previously identified by the original equipment manufacturer in a 2012 report.⁶

⁵For purposes of this report, the term “congressional direction” refers to both S. Rep. No. 112-173, at 23-24 (2012) and H.R. Rep. No. 112-705, at 885 (2012) (Conf. Rep.).

⁶In 2012, the original equipment manufacturer for Bradley Fighting Vehicles conducted an analysis of the cost of shutting down its York, Pennsylvania facility due to the anticipated decrease in demand for ground combat vehicles. Through this study and others, the original equipment manufacturers have expressed concern over potential production breaks and decreases in demand for ground combat vehicles, and the impacts of the decreased demand on costs, efficiency, critical skills, and suppliers.

Key Elements of a Study

Based on generally accepted research standards, key elements of a study include its design, execution, and presentation. The design of a study includes, for example, establishing the objectives, scope, and methodology of a study, and identifying assumptions related to the study. Design is an essential piece of the study—without a strong design, it is difficult to effectively execute the study and produce findings supported by valid and reliable evidence. Successful execution of a study involves ensuring the methodology is carried out as planned, or adjusted as appropriate to the evidence, and ensuring that study data are sufficiently valid and reliable for the study's purposes. Presentation of the study includes, for example, clearly and accurately documenting the findings, or results, of the study in a way that is relevant to the clients and/or stakeholders. A full list of the generally accepted research standards related to design, execution, and presentation of results by which we assessed the Army's industrial base study is included in appendix I.

The Study's Overall Approach Was Reasonable and Met Generally Accepted Research Standards

Based on our assessment of the Army study against generally accepted research standards, the Army's combat vehicle industrial base study's approach—including its design, execution, and presentation of results—was both reasonable and sound for its intended purposes. We determined the study's design was sound based on our assessment of the study's objective, scope, methodology, and assumptions. The study's objective addressed the congressional direction, which required the Army to assess the combat vehicle industrial base, the scope was comprehensively designed to achieve the study's objective, and the methodology was a reasonable and clearly stated way of addressing the study's objective. The study's assumptions, which underpin the design of a study, were generally reasonable and consistent, though some key assumptions could have been more explicitly stated. We found the study to be well executed because the methodology was consistent with the study objectives, study limitations were identified and reasonably mitigated, and steps were taken to ensure the data used in the study were valid and reliable for study purposes. Finally, with regards to presentation of results, the study's findings and conclusions were presented in a clear, comprehensive, and timely manner, with the analysis and findings going beyond what was required by the congressional direction. Overall, we found the study's design, execution, and presentation of results comported with generally accepted research standards, and as a result, we believe the study's key findings were reasonable and well supported.

The Study's Design Was Sound

We assessed the study's objective, scope, methodology, and assumptions and determined the study's design was sound. The study's objective was reasonable and appropriate in that it addressed the congressional direction. The study's scope was clearly defined and comprehensively designed to address the study's objective, and the overall methodology was consistent with the study's objectives. The study's assumptions were generally reasonable, although some could have been more explicitly stated.

The Study's Objective, Scope, and Methodology Were Reasonable

The study's objective was reasonable in that it addressed the congressional direction. Generally accepted research standards state that objectives outline what a study is intended to accomplish. The conferees for the National Defense Authorization Act for Fiscal Year 2013 directed the Army to assess the effects on the combat vehicle industrial base of decreased demand specifically related to the Bradley Fighting Vehicle, and the Senate Armed Services Committee directed the Army to report on its government-owned/contractor-operated tank production facility, which is where Abrams tanks are produced. The study's objective was to complete an assessment of the combined commercial and government combat vehicle industrial base and develop viable strategic alternatives to sustain that base within a constrained fiscal environment. This objective was broad enough to encompass not only the information on the Abrams tank and Bradley Fighting Vehicles requested by the congressional direction, but also to look more holistically at the combat vehicle industrial base (see figure 1).

Similarly, we found the study's scope to be clearly defined and comprehensively designed to address the study's objective. Generally accepted research standards state that a study's scope defines the subject matter that will be assessed and reported on, and the scope is directly tied to the audit objectives. The study's scope included all the key combat vehicles used by the Army, including the Abrams main battle tank, Bradley Family of Vehicles, Stryker Family of Vehicles, M109 Paladin Family of Vehicles, M88 Recovery Vehicle, M113 Armored Personnel Carrier Family of Vehicles, Ground Combat Vehicle, Armored Multi-Purpose Vehicle, and U.S. Marine Corps combat vehicles. While the study primarily focused on three programs—the Abrams, Bradley, and Stryker vehicles—this was appropriate given the congressional language and that these three vehicles comprise a large portion of combat vehicle production. The study also covered all of the relevant facilities involved in production, including the Joint Systems Manufacturing Center, the BAE facilities in York, Pennsylvania, the Anniston Army Depot, the GDLS facility in London, Ontario, and the Red River Army Depot. In addition to

the key facilities, the Army study's team conducted visits to 72 supplier locations, or about 28 percent of suppliers identified as a part of the industrial base for purposes of the Army study.

The study's overall methodology was reasonable, comprehensive, and clearly addressed the study's objective. Generally accepted research standards indicate that a study's methodology should be consistent with and address a study's objective. The study's methodology included an examination of the capability, capacity, and costs of both public and private combat vehicle manufacturing facilities as well as the ability of key suppliers to withstand enduring periods of low demand. To address the first part of the study's objective—assessing the combined commercial and government combat vehicle industrial base—the key methodology involved four elements: (1) conducting a current state assessment, (2) establishing the original equipment manufacturer/government cost baseline, (3) conducting a supplier base analysis, and (4) conducting a benchmark analysis. To address the second part of the study's objective—developing viable strategic alternatives to sustain that industrial base within a constrained fiscal environment—the key methodology involved two elements: (1) a scenario analysis, or using the data collected to develop and assess multiple scenarios for sustaining the combat vehicle industrial base; and (2) a network strategy plan, or developing potential alternatives for restructuring parts of the combat vehicle industrial base. Figure 2 below describes these key elements of the methodology in more detail.

Figure 2: Key Methodological Elements of the Study

Objective	Methodological element	Description
Assessing the combined commercial and government combat vehicle industrial base	Current state assessment	Identified facility and vehicle-specific information for combat vehicles, such as workforce competencies, capabilities, and requirements.
	Cost baseline	Identified costs of specific manufacturing processes at different facilities for various types of vehicles.
	Supplier base analysis	Identified critical suppliers, examined the business risk to each supplier associated with periods of low demand, and examined the potential for suppliers to mitigate this risk.
	Benchmark comparison	Compared cost and process elements for facilities in the combat vehicle industrial base to industry manufacturing baseline benchmarks.
Developing viable strategic alternatives to sustain that base within a constrained fiscal environment	Scenario analysis	Used the data and analysis from the efforts listed above to develop, evaluate, and rank multiple scenarios for sustaining the combat vehicle industrial base. This analysis included the use of sensitivity analysis. ^a
	Network strategy plan	Development of potential alternatives for restructuring parts of the combat vehicle industrial base.

Source: GAO analysis of Army study documentation. | GAO-15-548

^aSensitivity analysis involves identifying key elements and varying the assumed value of a single element while holding the others constant to identify the extent to which a conclusion relies on a particular value for that element.

In addition to assessing the combat vehicle industrial base, the study's methodology included an in-depth assessment of the potential costs of shutting down the York production facility. To identify and analyze these costs, the study's authors used the data collected as a part of their methodology for the assessment of the combined commercial and government industrial base. This analysis was responsive to the congressional direction to assess the financial impact and risk of a production break for the Bradley Fighting Vehicle.

The Study's Assumptions Were Generally Reasonable, Although Some Key Assumptions Could Have Been More Explicitly Stated

Based on our review of the study and supporting documentation, we believe that assumptions utilized by the study were generally reasonable and consistent with one another, although some key assumptions could have been discussed or defined more explicitly. Assumptions define the parameters for what will be included and how the study is executed. Generally accepted research standards note that assumptions should be

explicitly identified in order to understand the context of the study's results.

Of those assumptions we identified, among the most critical to the Army study's results were those associated with estimates for the costs of a production shutdown and restart of the commercial facility in York, Pennsylvania. Based on our review, we believe the Army study's assumptions related to the costs of a potential shutdown at the facility were generally reasonable because they were based on current information, such as updated procurement plans and recent contractor actions. For example, the Army's study assumed a two-year shutdown of the Bradley line followed by restart, which the study's authors termed a "warm shutdown," because the shutdown included an anticipated restart date. This assumption was reasonable because it was based on the Army's anticipated time frame for restarting production at the time of the study. Other assumptions that affected the estimates included inventory costs and employee costs. The Army study used an inventory cost estimate based on costs associated with the disposition of the inventory of the current Bradley production line at the York facility, and, similarly, the Army study's estimate included only the employee costs associated with the current Bradley production line at the York facility, which was appropriate since it was consistent with the assumption of a 2-year shutdown of Bradley production at this particular facility.⁷

Differing assumptions, in large part, explain the wide discrepancy in estimated shutdown and restart costs for the Bradley Fighting Vehicle production line found by the Army's study (\$53 million) and that of a 2012 original equipment manufacturer study (\$750 million). However, the Army's study appropriately cautions against comparison of these results, noting that the two studies had very different assumptions caused by differing time frames and actions taken by the Army and the original equipment manufacturer in the intervening time. Since the manufacturer's estimate was completed in 2012, the Army took actions such as directly investing in selected areas of the supplier base, such as in critical suppliers like an engine provider, and bought engines in advance of need, in order to protect that particular capability. The Army also accelerated the planned start date of various combat vehicle production efforts,

⁷At the time of the study it was not anticipated that the Abrams production line would be shut down, therefore the study focused on the potential Bradley production line shutdown.

including the Abrams and Bradley vehicles. The original equipment manufacturer initiated efforts to consolidate production by closing some satellite operations and consolidation of some operations within the York facility, among other actions. The costs associated with these actions were either incurred or avoided, and are therefore no longer relevant to an analysis on future costs to be incurred in a potential shutdown of the Bradley production line. The original equipment manufacturer agreed that the two studies' estimates could not be compared due to the differing assumptions used. The original equipment manufacturer also anticipated that there would be a much smaller discrepancy in the estimated costs of a shutdown were the numbers to be updated today, due to some of the factors discussed above, particularly, in their view, because many of the costs of a potential shutdown had already been realized. However, the original equipment manufacturer representatives also stated that they believed some costs would be higher than those estimated by the Army's study, such as the cost for requalifying suppliers after production started up.

With respect to other assumptions identified in the study, the study explicitly identified and appropriately varied assumptions about the expected demand for combat vehicles when developing scenarios for the combat vehicle industrial base using sensitivity analysis. Sensitivity analysis, a key characteristic for a credible study based on generally accepted research standards, involves identifying key elements and varying the assumed value of a single element while holding the others constant to identify the extent to which a conclusion relies on a particular value for that element. Varying assumptions of the values of specific elements assesses the robustness of results by analyzing alternative scenarios and identifying the extent to which an outcome is sensitive to a particular element (such as demand), and the study did so in this case.

While most assumptions were explicitly identified, not all were. Assumptions can mask uncertainties that affect the validity of findings. According to generally accepted research standards, assumptions underlying a study should be explicitly identified in order to provide a better understanding of how the analysis was conducted and how it reached its findings and conclusions. For example, a key assumption that was not explicitly identified was that the study assessed risk from the perspective of the Army. In other words, risk was assessed assuming that, at some future date, the Army would not have access to a needed manufacturing capability or critical supply component, versus from the perspective of the risk to the original equipment manufacturers or the

individual suppliers. This was presented in the study as a finding; however, we believe it to be an assumption.

In addition, the study could have included more explicit information about the assumptions used to define the minimum sustainment rate. The study noted that it used the minimum sustainment rates as derived by the original equipment manufacturers, but did not include specific information on how that minimum sustainment rate was derived. Army and commercial industry officials have noted that minimum sustainment rate is a somewhat subjective term because different organizations may include different cost assumptions in assessing the minimum production rate it can sustain financially. Given that a change in the minimum sustainment rate could impact the findings of a study, more explicit information on how it was derived would have been useful information for the study's stakeholders when viewing the study and considering the results. However, we do not believe that the lack of explicitly stated information materially affected the results of the study, but if better explained, would provide clearer understanding of the assumptions.

Execution of the Study Was Reasonable

We found the execution of the study to be reasonable, in that the study was executed in accordance with the methodology. Also, during the execution of the study, various limitations arose that were identified and reasonably mitigated. Finally, as part the execution of the study, the Army took sufficient steps to ensure the data were valid and reliable for the study's purposes.

The Study was Executed in Accordance with the Defined Methodology

The study was executed in accordance with its defined methodology. As noted previously, generally accepted research standards indicate that a study's methodology should be consistent with and address a study's objective. Specifically, the study's authors successfully conducted each of the six analyses—the current state assessment, cost baseline, supplier base analysis, benchmark comparison, scenario analysis, and network strategy plan. For example, to establish a cost baseline, the study's authors identified the costs of various manufacturing processes for combat vehicles at different production facilities by requesting data from manufacturers and suppliers, observing production operations, walking along production lines and interviewing production workers about production operations at both government and commercial manufacturing facilities. In another example, for the scenario analysis, the study's authors used the information collected through the current state assessment and the cost baseline to develop a spreadsheet-based model to examine the financial consequences to various manufacturers and

suppliers in the industrial base based on different levels of demand.⁸ These scenarios were run through the model to help the Army develop potential courses of action to alter the structure of the combat vehicle industrial base.

By conducting the six analyses, the study's authors were able to identify key risks to the combat vehicle industrial base. For example, based on the information collected and analyzed as a part of its supplier based analysis, including interviews and site visits with 72 suppliers, the study identified several key suppliers that required direct action by the Army to ensure that production of key items continues during the period of low demand for combat vehicles. Additionally, based on the information collected and analyzed through an assessment of critical manufacturing skills, a part of the methodological step in the current state assessment, the study identified the most critical and at-risk skills as various types of welding and inspection. These findings helped to inform the Army's direct investments in the combat vehicle industrial base in fiscal years 2013 and 2014. In our interviews, the original equipment manufacturers expressed some concerns that the number of critical skills identified was too low and believed replacing these skills would cost more and take more time than anticipated by A.T. Kearney, but we found that the study's authors established reasonable criteria by which they identified those critical skills. The study's authors also reasonably applied those criteria to identify the critical skills.

As a part of executing the defined methodology, contractor-specific preliminary findings were presented to the original equipment manufacturers in May 2013. This provided the original equipment manufacturers an opportunity to weigh in on the accuracy of the findings related to their facility. In our discussions with the original equipment manufacturers, they generally indicated that the study's authors were comprehensive in their efforts to collect the depth and breadth of data needed to reach their conclusions. Additionally, the suppliers were generally very positive about the study.

⁸This model was developed to support the continued analysis of future state industrial base environmental changes.

Study's Limitations Were Generally Identified and Reasonably Mitigated

During the execution of the study, we found that various limitations were identified and reasonably mitigated. Studies generally have limitations. Research standards do not call for the elimination of all limitations, but do call for limitations to be identified, assessed, mitigated, and explained. Some of the key limitations we noted in our review of the Army's study were: (1) the study's authors were not provided with a comprehensive list of suppliers; (2) there was a relatively low completion rate on the survey sent to the suppliers; (3) the study's authors were not always provided with the facility data they requested; and (4) facilities included different elements in their overhead rates, potentially limiting comparison of overhead rates across the differing facilities.

Based on our review of the study, the study's authors reasonably mitigated the limitation of not being provided a comprehensive list of suppliers in the combat vehicle industrial base. The original equipment manufacturers elected, for business competition reasons, not to furnish information that clearly identified all the suppliers for each of the vehicles in the industrial base. For instance, one manufacturer told us they provided the information for their at risk suppliers. To mitigate this lack of information, the study's authors obtained as much supplier information as possible from a variety of other sources, such as the Army Materiel Command's Industrial Base Baseline Assessment; a Department of Defense database of suppliers; combat vehicle program manager interviews; other industrial base studies; a sustainment engineering risk assessment; ground combat systems consolidated parts lists; and lists of long-lead items for various vehicles.

Another limitation the study's authors encountered was a relatively low response rate—about 25 percent—to a survey sent to about 200 suppliers. The suppliers surveyed include those for key parts of the various combat vehicles, such as engines, transmissions, radar and target acquisition components, as well as many other smaller parts. The study's authors took steps to obtain more information about the non-respondents, such as obtaining publically available information on the companies, including credit rating information, to develop an accurate company business profile. According to the study's authors, by contacting non-responding suppliers and reviewing company information, they identified a number of possible reasons for nonparticipation, some of which indicated that a subset of these suppliers should not have been included in the original survey. For example, some suppliers that were sent the initial survey were no longer in business, and others indicated that their company no longer pursued ground combat vehicle work. Further, in contacting non-responding suppliers, the study's authors made

contact with over 20 non-responding suppliers whom, while they did not respond to the survey, did agree to participate in the study site visits. This effectively increased the supplier participation rate in the study. While the authors did not formally compare the respondents to the non-respondents—an additional analysis step that could have further mitigated concern about the response rate—we believe the steps taken to examine the non-respondents were generally reasonable. The study's authors also asserted that they do not think they missed any key suppliers.

Another limitation faced by the study's authors was the fact that, in some instances, suppliers were reticent to provide information on their facilities and other costs given the proprietary nature of the information. To mitigate this limitation, the study's authors used industry benchmark data as well as their own industry experience to estimate a range within which they expected the costs to fall. The authors then provided this estimated cost information to the supplier in question to discuss whether the estimate was a reasonable proxy for the specific cost data. The study's authors told us that these efforts often resulted in the supplier sharing the actual data.

Finally, the study's authors also mitigated a limitation on their ability to compare and contrast cost data related to factory overhead rates. Because different production facilities charge different activities to different accounts, the calculation of overhead rates had to be standardized to ensure the comparison of like items. The study's authors examined the time charges for accounts that contribute to factory overhead at different facilities and made efforts to normalize the data, ensuring that overhead rates for each facility were generally comprised of the same elements. This allowed for a like comparison, or a comparison of similar cost elements, for the production costs at various facilities within the combat vehicle industrial base.

**The Army Took Sufficient
Actions to Ensure the Data
Were Valid and Reliable for the
Study's Purposes**

Research standards note that the data used in a study should be valid for the intended research purpose; in other words it represents what it purports to represent. To ensure that valid data were obtained, the study's authors went to the original sources to obtain relevant information and sought clarification to make sure they understood the data provided. For example, they obtained information on government expenses at the Joint Systems Manufacturing Center directly from the Abrams program office. Additionally, the production facilities within the scope of the study, such as the original equipment manufacturers and their suppliers, provided their organization's financial data. The study's authors noted that

this information had also been reviewed by the Defense Contract Management Agency, the government agency responsible for, among other things, monitoring contractors' management of their indirect costs. Each facility provided the baseline data that was used to develop scenarios (cost, hours per unit, manufacturing capability, etc.) and the final product of the analysis was then shared with each facility. Further, in situations where a firm may have elected not to provide company data, the study's authors reported they used various sources of information to estimate the firm's financial information, and then met with the firm to review those estimates for accuracy. In some cases, the study's authors reported this led to the firm providing the actual data to them.

Reliability refers to the consistency and verifiability of the data's measurement. To ensure the data's reliability, the study's authors went back to the data sources, in many cases multiple times, to review their methods and ensure they were using the data correctly. For example, the financial analysis for the Bradley engine involved collecting cost information, such as wholesale and dealer list costs for the major subcomponents of the engine, and generating an analysis using these inputs. The study's authors reviewed this data and analysis with the supplier's general manager and working team to ensure the accuracy of the data. The study's authors also met multiple times, both in person and via teleconference, with original equipment manufacturers and suppliers to review their methods and the results of their analysis. Original equipment manufacturers and government facility managers we spoke with reported multiple visits and operations related discussions at their respective facilities. Additionally, the key suppliers we spoke with told us that the study's authors returned on multiple occasions to verify the accuracy of the information and the soundness of their methods for using that information. These actions effectively served to create a feedback loop that was used to verify the accuracy of the corresponding data, analysis, and results.

The Findings and Conclusions Were Presented in a Clear, Comprehensive, and Timely Manner

The findings and conclusions were presented in a clear, comprehensive, and timely manner. In terms of clarity, the key findings were explicitly laid out and the conclusions were clear in the final report. For example, the final report clearly concluded that there was significant excess in large structure machining capacity throughout the ground combat vehicle manufacturing network, and linked this conclusion to the study's assessment of manufacturing capabilities. This conclusion, similar to others in the study, was reasonable in that it flowed logically from the evidence collected based on the methodology. In addition to being clear, we found the study's findings to be comprehensive, covering key

commercial and government facilities in the combat vehicle industrial base in addition to dozens of suppliers. Further, the study addressed the combat vehicle industrial base from many facets, including the capability, capacity, and cost, looking at a number of key issues, including manufacturing capacity, critical skills, critical suppliers, and the potential impacts of shutting down key facilities. Finally, the study results were presented in a timely manner. The Army issued a contract with the management consulting firm in October 2012 and the study's preliminary results were provided to the Army in April 2013, interim briefings were provided to key Congressional committees later in 2013, with a final report submitted to these committees by the Army in April 2014.

The study provided relevant information to key stakeholders, particularly the Army and congressional defense committees. For example, the final report addressed the information required by congressional direction. Specifically, the report included an assessment of the Bradley Fighting Vehicle industrial base and the Army's analysis and plans for using the Joint Systems Manufacturing Center in Lima, Ohio, the location where the Abrams tank is produced. In addition, the study went beyond the information required by congressional committees. For example, in addition to the Abrams and Bradley assessments, the study's scope also included additional vehicles such as Strykers, M109 Paladins, M88 Hercules, M113 Armored Personnel Carriers, Ground Combat Vehicle, Armored Multi-Purpose Vehicle, and U.S. Marine Corps combat vehicles. Additionally, the study analysis included the identification of potential courses of action for the future, such as consolidation of production at certain facilities.⁹ These options were not required to be included in the report to the congressional defense committees. However, an Army official told us that having this information at hand allows the Army to be better prepared if options for consolidation need to be considered in the future.

While the Army and the study's authors provided interim briefings and facility specific information to key contractors, as noted previously, the original equipment manufacturers and the suppliers we held discussions with reported they had not received copies of the final report, so they were unable to comment fully on the nature of the final report's findings.

⁹The congressional direction did not delineate that the Army identify options for consolidating the combat vehicle industrial base, and the options developed as a part of the study were not included in the final report to the congressional defense committees.

The Army told us that the original equipment manufacturers and other suppliers had not been provided with the final report due to the classification of the report as “for official use only.”

Overall, we found the study’s design, execution, and presentation of results were executed in accordance with generally accepted research standards. Based on this, we also believe the key findings discussed in the study were reasonable and well supported.

Agency Comments

We are not making any recommendations in this report. We requested comments on a draft of this report from DOD. On June 8, 2015, we received an email indicating that the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology agreed with the draft report as written. DOD did not provide any technical comments.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, and the Secretary of the Army. In addition, the report is available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or makm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are listed in appendix III.



Marie A. Mak
Director
Acquisition and Sourcing Management

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Appendix I: Generally Accepted Research Standards Used to Assess the Army’s Combat Vehicle Industrial Base Study

Design: Is the study well designed?

1	2	3	4	5	6	7	8	9
Is the study's design clear?	Is the study's objective clearly stated?	Is the study's scope clearly defined?	Are the assumptions explicitly identified?	Are the assumptions reasonable and consistent?	Are the assumptions varied to allow for sensitivity analyses?	Are major constraints identified and discussed?	Are the scenarios that were modeled reasonable ones to consider?	Do the scenarios represent a reasonably complete range of conditions?

Execution: Is the study well executed?

1	2	3	4	5	6	7	8
Is the study's methodology consistent with the study objective?	Are the study's objectives addressed?	Were the models used to support the analyses appropriate for their intended purpose?	Were the data used valid for the study's purposes?	Were the data used sufficiently reliable for the study's purposes?	Were any data limitations identified and were the impact of the limitations adequately explained?	Were any modeling and simulation limitations identified, explained and justified?	Have the models used in the study been described and documented adequately?

Presentation of results: Are the results timely, complete, accurate, concise, and relevant to the client and stakeholders?

1	2	3	4
Do the results of the modeling support the report findings?	Does the report present an assessment that is well documented?	Are the conclusions sound?	Are the study results presented in the report in a clear manner?

Source: Generally accepted research standards adapted from GAO-06-938. | GAO-15-548

Appendix II: Scope and Methodology

The Joint Explanatory Statement to Accompany the National Defense Authorization Act for Fiscal Year 2014 included a general provision for GAO to assess the Army's April 2014 Study,¹ and report on the reasonableness of the study's methods, including an assessment on the sufficiency, validity, and reliability of the data used to conduct the study, and any findings and recommendations on the combat vehicle industrial base. To guide our assessment of the study, we identified generally accepted research standards for the design, execution and presentation of findings that define a sound and complete study. These standards were developed by reviewing research literature and Department of Defense (DOD) guidance and identifying frequently occurring, generally accepted research standards that are relevant for defense studies that define a quality or sound and complete study and initially used in a prior report ([GAO-06-938](#)).² We adapted the questions related to these standards as appropriate for the current assessment. Appendix I provides a list of these adapted standards and associated questions.

To gather the evidence against which to assess the study, we met with the study's authors, received a briefing on the study, and requested relevant study documentation. This included the Army's contract with the management consulting firm, backup slides that detail the methodological pieces of the study; study briefings, both interim and final; and the final report to congressional defense committees issued in April 2014. To determine the extent to which the Army's report addressed the information required by the Senate Armed Services Committee and congressional conferees for the National Defense Authorization Act for Fiscal Year 2013, we analyzed Senate Report 112-173 and Conference Report 112-705 for the National Defense Authorization Act for Fiscal Year 2013 to identify each element of the congressional direction for the Army report, and compared those elements to the study's objective, methodology, and findings. To develop an understanding of how and why industrial base assessments are conducted, we reviewed applicable DOD industrial base policies and guidance, such as DOD Instruction 5000.60, Defense Industrial Base Assessments, and Army Regulation 700-90,

¹The Army's report was entitled "M1 Abrams Tank Upgrade and Bradley Fighting Vehicle Industrial Base Study: Report to Congress."

²GAO, *Defense Transportation: Study Limitations Raise Questions about the Adequacy and Completeness of the Mobility Capabilities Study and Report*, [GAO-06-938](#) (Washington, D.C.: Sept. 20, 2006).

Army Industrial Base Policy. We interviewed the study's authors to better understand how the study was conducted, and to develop an in-depth understanding of the scope, methodology, analyses, assumptions, limitations, data sources, and data validity and reliability steps taken as a part of the study. We also held discussions with Army officials from the Program Executive Office for Ground Combat Systems, which is responsible for providing ground combat equipment, including combat vehicles, to the warfighter, about the study scope and methodology, the data provided to the study's authors by the Army and by DOD, and the steps taken to ensure the data was sufficiently valid and reliable for the study's purposes. To develop an understanding of their knowledge and perspectives on the Army study, as well as their perspectives on the combat vehicle industrial base more broadly, we also met with officials from several DOD entities, including the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy and the Defense Contract Management Agency.

To obtain a better understanding of the ground combat vehicle industrial base, we visited the three government and commercial facilities that comprise the primary facilities for the production and maintenance activities for ground combat vehicles and interviewed knowledgeable government officials and representatives from the two original equipment manufacturers about their participation in the study, the types of data provided for the study, the nature and extent of their interactions with the study's authors, as well as their observations or opinions regarding the study. Specifically, we visited the government-owned, contractor-operated Joint Systems Manufacturing Center in Lima, Ohio, the Anniston Army Depot in Anniston, Alabama, and BAE Systems' York, Pennsylvania, production facility. We also interviewed representatives from six suppliers that participated in the study to obtain their perspectives on the study. We selected these suppliers with a goal of obtaining suppliers that represented a mix of items produced for the combat vehicles and with consideration of the suppliers' perceived criticality to the combat vehicle industrial base. The views of these suppliers cannot be generalized to the views of all those suppliers that participated in the study.

To assess the study, two GAO analysts individually evaluated the Army study against standards for a sound and complete study using a scorecard methodology to indicate whether the evidence we obtained addressed each of the questions associated with the standards. Based on a preliminary review of the study and supporting documentation, and consultation with GAO specialists in the areas of economics, survey and research methods, the GAO team followed up with written requests for

additional information and clarification from the Army and the study's authors. The two analysts then completed their independent analyses, and we compared the two sets of observations and discussed and reconciled any differences. For reporting purposes, we determined that qualitative assessment ratings provide the best explanation of the nuances of the analysis and findings, rather than numeric ratings for each individual standard.

We conducted this performance audit from July 2014 to June 2015 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Marie A. Mak, (202) 512-4841 or makm@gao.gov.

Staff Acknowledgments

In addition to the contact named above Janet McKelvey, Assistant Director; Bill Allbritton, Analyst-in-Charge; John Beauchamp; Virginia Chanley; Farrah Graham; Sylvia Schatz; Anne Stevens; and Robert S. Swierczek made key contributions to this report.

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