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A comparative analysis of options for preserving the tank industrial base

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THESIS

A COMPARATIVE ANALYSIS OF OPTIONS FOR PRESERVING THE TANK INDUSTRIAL BASE

by

Juan J. Hernandez

March 1993

Principal Advisor: Thomas H. Hoivik

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This thesis analyzes the impact of potential closure of the sole tank production facility in the United States, including the effects of closure on future tank production. The analysis is based on the FY93 DOD budget which appropriated funds for upgrades to existing M1 Abrams tanks through 1995. Three possible alternatives to preserving the tank industrial base are presented and analyzed with respect to applicable factors currently facing decisionmakers in DOD, Congress and industry. The three alternatives are: (1) terminate production upon completion of the initial upgrade in 1995, (2) continue the upgrade from 1996 to 1999, or (3) slow down existing production rates to stretch out production and minimize production stoppages. These alternatives are analyzed utilizing factors such as workforce effects, costs, subcontractor base impact, mobilization/surge impact, spare parts requirements, and operational effectiveness. The thesis concludes with a recommendation on how to preserve the tank industrial base with additional recommendations and areas requiring further study. The methodology utilized here can be applied to other DOD systems and programs dependent on a single manufacturer for systems facing a similar predicament.

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A Comparative Analysis of Options for Preserving the Tank Industrial Base

by

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ABSTRACT

This thesis analyzes the impact of potential closure of the sole tank production facility in the United States, including the effects of closure on future tank production. The analysis is based on the FY93 DOD budget which appropriated funds for upgrades to existing M1 Abrams tanks through 1995. Three possible alternatives to preserving the tank industrial base are presented and analyzed with respect to applicable factors currently facing decisionmakers in DOD, Congress and industry. The three alternatives are: (1) terminate production upon completion of the initial upgrade in 1995, (2) continue the upgrade from 1996 to 1999, or (3) slow down existing production rates to stretch out production and minimize production stoppages. These alternatives are analyzed utilizing factors such as workforce effects, costs, subcontractor base impact, mobilization/surge impact, spare parts requirements, and operational effectiveness. The thesis concludes with a recommendation on how to preserve the tank industrial base with additional recommendations and areas requiring further study. The methodology utilized here can be applied to other DOD systems and programs dependent on a single manufacturer for systems facing a similar predicament.

TABLE OF CONTENTS

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to analyze the impact of the potential closure of the only tank production facility in the United States. Additionally, three possible alternatives to preserving the tank industrial base will be presented and analyzed with respect to applicable factors facing DOD, Congress and industry.

B. BACKGROUND

The tank industrial base is unique and essential to the readiness of the U.S. Army. There is no commercial counterpart. The world is becoming more unstable and the need for U.S. peacekeeping strength is greater than ever. To let the tank industrial base whither due to an unclear industrial base plan is to compromise future readiness, tank program options and U.S. resolve to support its allies. Congressional commitment to preserve the tank industry for the near term by funding the first phase of the Abrams tank upgrade signifies the necessary awareness to prepare for the next war. As Appius Claudius the Blind stated before the Roman Senate, "if you value peace, be then prepared for war." Without a functioning and proactive industrial base to support the standing army, the stage for failure is set.

The M1-series tank assembly line in Lima, Ohio, is currently the only open tank factory in the U.S. The last M1A1 tank for the U.S. Army rolled off the production line in March 1993 and Foreign Military Sales (FMS) production will end in 1995. Congress has approved upgrades of older model M1s to the M1A2 in the FY93 budget. The only other tank assembly line at Detroit, Michigan, was closed in October 1991. As a result of the current trend to downsize the military, it is possible that the tank plant at Lima, Ohio, may remain idle from 1996 beyond 2000. The termination of the Block III tank program in 1992 may lengthen this idle period if no follow-on tank is developed in the near future or the second part of the M1 to M1A2 upgrade plan, due to take place from 1996 to 1999, is not funded.

As a result, General Dynamics, producer of the M1 tank, is trying to sell the M1 tank to Saudi Arabia, Egypt, Pakistan, Canada and the United Arab Emirates and is pushing DOD and Congress to continue retrofitting older M1s and M1A1s to M1A2s in order to keep the Lima plant open and preserve the tank industrial base.

Even these proposed alternatives may not keep the factory open long enough to transition immediately into Block III or Future Main Battle Tank (FMBT) production. The U.S. Congress has directed that DOD retrofit older M1s to M1A2s in 1991, yet DOD contested the upgrade plan by requesting a rescission of FY92 appropriations for upgrades. Congress subsequently denied the rescission. Even with the funds appropriated for the first 210 tanks, the Army will have a difficult time obtaining funds to execute the remaining reconversion program.

Consequently, the debate between Congress and DOD is whether to: (1) shut down the factory completely and mothball it until new production starts in the next century, (2) slow down existing rates of production such that the factory will remain open until it is time to retool for Block III or FMBT production, or (3) keep the factory open to continue conversion of early model M1 and M1A1s into the M1A2 tank. The situation facing DOD and Congress typifies some of the problems that affect industrial base preparedness as the military shrinks in size and weapon systems acquisition is slowed down or halted.

C. THESIS OBJECTIVES

The objectives of this thesis are to provide the Army, DOD, and congressional decisionmakers an insight into what should be done with the only open tank factory in the United States. By using a case study format, a process to analyze this issue is presented that can be applied to other programs dependent on a single manufacturer for systems that are facing a similar predicament.

D. RESEARCH QUESTIONS

1. Primary

Upon completion of Abrams tank production in 1995, should DOD close the only tank production facility in the United States, or keep it open until a new generation tank is built?

2. Subsidiary

- How will the absence of a U.S. tank production facility from 1996-2001 affect future tank production, especially the Block III tank?
- Will skilled workers be lost? Can they be replaced?
- How will the FY93 DOD budget affect the tank production industrial base?

- What will it cost the Government to reopen the tank factory should the factory close?
- What will be the effect of plant closure on the subcontractor base?
- How will spare parts requirements for the existing tank fleet be satisfied?
- Under what conditions should DOD attempt to maintain a minimum tank production capability for such circumstances as mobilization or foreign military sales?
- How will the Army deal with the existing fleet, along with other operational issues, should it keep existing M1s and M1A1s instead of buying the Block III or M1A2 tank?

E. RESEARCH SCOPE AND LIMITATIONS

This case study focuses only on U.S. tank production and the effects of DOD acquisition strategies and plans on a single source within the defense industrial base. Since this issue continues to be debated between Congress, DOD, and industry and the FY93 budget has partially preserved the tank industrial base through 1995, the scope of this thesis will be limited to FY93 budget considerations.

F. METHODOLOGY

The thesis research and analysis first examines lessons learned from the defense and tank industrial base during World Wars I and II, Korea, and Vietnam and how the industry handled declines in post-war weapon systems acquisition. The thesis then develops three possible courses of action on methods proposed by decisionmakers to sustain the tank industrial base. The effects of these three options are then analyzed with respect to the following issues, 1) the tank industrial base workforce, 2) dollar costs required to implement each option, 3) effects on the subcontractor base, 4) impact on mobilization requirements, and 5) operational effectiveness considerations. Finally, conclusions and recommendations are presented with lessons learned that may be applicable to systems facing a similar predicament in the years ahead.

G. LITERATURE REVIEW

Background and policy information was obtained from the Defense Technical Information Center (DTIC)/Defense Logistics Studies Information Exchange (DLSIE) databases, professional journals, and published studies. Additional information was obtained by corresponding with the Armor School, Program Executive Office (PEO)-Armored Systems Modernization, and Program Manager (PM)-Abrams in the Tank Automotive Command for current literature, technical data and newly published studies on the subject. General Dynamics-Land Systems Division (GDLS), Congressional Budget Office (CBO) and the General Accounting Office (GAO) were additional sources for technical data. Additional assistance was received from the Institute of Land Warfare at the Association of the United States Army (AUSA), from the American Defense Preparedness Association (ADPA), and the Sterling Hobe Foundation in Washington, D.C.

II. BACKGROUND

A. THE INDUSTRIAL BASE

The economic and political situation facing the tank industrial base reflects problems that have permeated throughout the history of the U.S. defense industrial base since World War I. A combination of governmental efforts to coordinate industrial base policy and industry's effort to provide those products required for the nation's defense has resulted in many successes and just as many failures.

In a 1988 industrial base study published by the Center for Strategic and International Studies (CSIS), the industrial base is defined as the "aggregate ability to provide the manufacturing, production, technology, research and development, and resources required to produce materials for the common defense of the U.S."[1] Some of the implicit assumptions in this definition are that any firm that provides goods for national defense, whether commercially owned/operated, Government owned/operated, or domestic or foreign based is part of the industrial base. Also incorporated into this definition is the belief that the U.S. defense industrial base contributes to deterrence strategy in three ways: peacetime efficiency, technological competitiveness, and flexibility in a crisis. This contribution to deterrence assumes "that peace will be the

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[1]James Blackwell, *Deterrence in Decay: The Future of the U.S. Defense Industrial Base*, The final report of the CSIS Defense Industrial Base Project, Washington, D.C.: Center for Strategic and International Studies, May 1989, p. 12.

normal state of U.S. relations and that peace will be sustained by demonstrated readiness and willingness to fight to protect national interests."[2]

Additionally, the defense industrial base provides the military technologically superior materiel in order to overcome the disadvantage in being outnumbered as was typified by the U.S. military posture in Europe during the Cold War and more recently Desert Shield/Storm. Because deterrence may not always preserve the peace and because there is risk that low-level threats may bring the U.S. into conflict, the defense industrial base has to retain some flexibility to convert from peacetime research and development/production to wartime readiness requiring a short-term surge, long-term expansion, or postwar recovery.

B. THE TANK INDUSTRIAL BASE, 1917-1945

1. 1917-1940

The U.S. entered World War I in mid-1917 unprepared for a major world war. It had not foreseen the requirements that would be placed on the industrial base and as a result, it was in 1917 that the Government made the decision to manufacture a modified version of the French Renault light tank and components for the British Mark VIII heavy tank (the British Mark VIII would be partially manufactured in the U.S. with final assembly to occur in France). Large-scale production was planned for a small 3-ton tank and a larger tank with Ford Motor Company. Work was in progress on 23,405 tanks in the U.S. by November 1918. Because of the long lead time required to build

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[2]Blackwell, p. 13.

tanks, emerging new technologies, and the late mobilization of industry to a wartime posture, only 952 Renault light tanks, 100 Mark VIIIs and fifteen Ford 3-ton tanks were actually produced with none ever committed to combat in France.

In 1921, the Medium A tank program was initiated with similar models of tanks following in 1922 and 1925. The Medium A was followed by the Medium T2 in 1930 under the direction of Walter Christie. The T2 incorporated the innovative Christie suspension system and attained a top speed of 42.5 miles per hour, twice the speed of the Medium A tank. Soon afterwards, the Ordnance Department developed the 11-ton Medium T4 tank but because of the Depression, few tanks were purchased by the Army. As a result of the Depression and a small army dominated by horse cavalry advocates, the total number of tanks in the inventory stood at 464 as of May 1, 1940, or the total production since 1935. In the meantime, 1938-1940 saw newer designs culminating in the Medium T6 tank, subsequently redesignated the M4 Sherman and mass produced from July 1940 until the end of the war.

2. 1940-1945

World War II saw the establishment of the tank industrial base as U.S. industry met the challenge of fighting a two-front war. In sum, the defense portion of the Gross National Product (GNP) went from two to forty percent (the defense portion of GNP today is between five and six percent). Total tank production in World War II was 88,410 tanks. Seventeen factories in the U.S. produced tanks from 1940-1945 that included light, medium, and heavy tanks. Tank production by year was as follows:

TABLE I
WORLD WAR TWO TANK PRODUCTION

Year	Tanks Produced
1940	331
1941	4052
1942	24997
1943	29497
1944	17565
1945	11968

Source: Gutmanis.

C. THE TANK INDUSTRIAL BASE, 1945-1980

1. The Korean War

When the Korean War broke out in 1950, the U.S. was slightly better prepared than it had been for World Wars I and II. "It had retained a production base theoretically capable of supporting the force. However, due to inadequate funding of defense needs, the Army...was in a poor readiness state."[3]

The private sector had operated a defense industry that had developed and sustained post-World War II production requirements. Aiding their survival, production for the Korean War was built out of World War II facilities that either had continued to operate or could be rapidly reopened because the previous war had recently ended. In

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[3]LTC David T. Bullock, U.S. Army, "Can The United States Industrial Base Respond Adequately To the Need For Rapid Tank Production During Full Mobilization?" Executive Research Project S13, Fort McNair, D.C.: Industrial College of the Armed Forces, 1988, p. 4.

addition, the tank industrial base was being sustained by World War II mobilization planning, but in reality, the Army-owned tank plants were in a poor readiness state.

The Army existed in a budget constrained environment prior to the Korean War and had no money for new procurement to include tanks. For other than procurement items, the Army computed its requirements basing its calculations on bare essentials. But it still typically found the final appropriation well below its budget request. For example, the Ordnance Department's FY48 budget request estimated an Army budget of $750 million to procure essential ammunition and equipment, storage and distribution of ordnance material, maintenance of standby plants and arsenals, training, and research and development. The Bureau of the Budget cut the request to $275 million, with Congress appropriating $246 million. As a result, the armor force was critically lacking in new tanks at the initiation of hostilities and no new tanks were expected for fielding until 1952.

The armor force at the beginning of the Korean War stood as follows:

TABLE II
THE ARMOR FORCE IN 1950

Tanks On Hand	Type
900	Serviceable M24 Chaffee light tanks
2557	Unserviceable M24 Chaffee light tanks
1826	Serviceable M4A3 Sherman medium tanks
1376	Unserviceable M4A3 Sherman medium tanks
319	Serviceable M24 Patton heavy tanks

Source: AUSA Background Brief No. 40.

In sum, development of Army weapons and combat vehicles continued at a decelerated rate, while no funds were made available for improvements to existing systems.[4] In the Far East Command, MacArthur's forces had not had their tanks replaced since 1945 and they possessed no medium tanks in their inventory. As a result, even though U.S. technology was the best in the world, it remained on the drawing board and in the laboratories. The outbreak of hostilities resulted in disaster for U.S. tanks as they were easily outmatched by the better Soviet-equipped North Korean tanks.

2. 1950-1973

In a report to the National Security Council (NSC) published on 14 April 1950, *NSC-68* concluded that if unchecked, the Soviet Union would attempt to control Europe. Consequently, *NSC-68* provided an "intellectual rationale for the creation of a state of operational and mobilization readiness aimed at thwarting the Soviet Union."[5] This document became the basis for passage of the Defense Production Act (DPA) of 1950. The combination of lessons learned from the Korean War and the U.S.'s role as the world's policeman in the Cold War, now gave the Government the ability to formalize guidance to industry and DOD through the DPA not only in war, but in peace as well.

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[4]Association of the United States Army, *The U.S. Army Between World War II and the Korean War*, Arlington, VA: AUSA Institute of Land Warfare, Background Brief No. 40, March 1992, p. 5.

[5]Roderick L. Vawter, *Industrial Mobilization: The Relevant History*, Fort McNair, D.C.: National Defense University Press, 1983, p. 42.

The DPA was the only significant legislation governing the industrial base. Its fundamental purposes were to (1) provide mobilization capability that would be required in war, (2) provide authority to assign priorities to Government contracts, and (3) allocate materials and facilities for national defense. The Department of Commerce had statutory responsibility for the DPA, with authority further delegated to the Federal Emergency Management Agency (FEMA). From the 1950s until recently, the DPA and provisions of the Defense Authorization Act were the only legislation governing the industrial base. These laws came under conflicting jurisdiction in Congress with the Authorization Act coming under House and Senate Armed Services Committee jurisdiction and the DPA coming under Senate and House Banking Committee jurisdiction. This led to an ineffective and uncoordinated industrial base policy that lasted forty-three years.

Additionally, OSD provided guidance to industry in order to perpetuate the defense industrial base and prepare the nation for mobilization. It was issued in the following format.

a. Preferential Planning List

The Preferential Planning List (PPL) identified key end items essential to national survival and was prepared by DOD. Also known as the Thousand Items List, the Services were directed to identify key end items for which detailed mobilization planning would be executed. This list kept key items down to manageable numbers and provided for planning in-depth for major items. The approval authority to place items on the list came from DOD. To maintain this list, the Services and industry were forced to keep open communications and identify mobilization priorities in the industrial base.

b. Production Allocation Program

The Production Allocation Program (PAP) gave every essential manufacturer of military items and equipment the details in advance of mobilization on what to produce, for whom, and how much to produce. It also told the Services the source for specific items. The PAP was designed to reduce interservice rivalries for production capacity at a single plant. Plant usage under wartime conditions and military mobilization production schedules was established by a team consisting of an Armed Services Procurement Planning Officer (ASPPO) and plant representative.

c. Industrial Defense Program

The Industrial Defense Program (IDP) provided for the development of a list of critical facilities, such as factories, bridges, and power generating stations, necessary for production and delivery of essential military items. Also known as the Key Facilities List (KFL), it became the basis for planning industrial defense against both a threat and natural disasters. Each Service was assigned responsibility for certain facilities on the KFL.

d. Industrial Preparedness Measures Program

The Industrial Preparedness Measures Program (IPMP) was aimed at identifying and eliminating mobilization and production bottlenecks before the emergency actually occurred. It was implemented by contracts between Government and industry that ranged from a simple study to funding for new production processes. This program covered nearly all aspects of industrial mobilization planning activities.

e. *Priorities and Allocation Program*

The Priorities and Allocation Program expected to minimize costly delays in rapid conversion to military production at mobilization day. It was authorized by the DPA and was to be continued without an interruption until mobilization day was declared.

All of these programs intended to prepare the nation for war with the Soviet Union and the Warsaw Pact. Yet they were never fully executed and even as the nation went to war in Vietnam, production was never mobilized; however, a steadily growing flow of defense dollars permitted a market response to the increased defense demands of that conflict.[6] Because the Vietnam War gave industry a lead time to react, rigid wartime controls and a mobilization effort were unnecessary. However, war material procurement competed with peacetime commercial production, causing shortages of some items. Because Vietnam was not a war that required large numbers of tanks due to the nature of the warfare, tank production remained at peacetime levels. The decisions made during the Vietnam years would have damaging effects on industrial base policy well into the 1980s.

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[6]Blackwell, p. 11.

3. The 1973 Yom Kippur War

During the 1973 Yom Kippur War, the U.S. discovered its inability to support the quick and lethal warfare that typified the ten-day October 1973 War in the Middle East. Israeli tank losses were unpredictably high in short but extremely violent armored warfare. The U.S. was forced to provide over 1000 M60 tanks to Israel from war reserves in Europe and the active inventory, because the tank industry was unable to produce the requisite number of tanks in time.

Only two factors prevented the Arab coalition from achieving a tactical victory against the Israelis. First, the Israelis were able to repair and rearm 800 tanks during the war and second, the massive airlift of American tanks from the U.S. and Europe provided desperately needed armor to the Golan and Sinai fronts. As a result of the war, DOD directed Chrysler to increase production from 30 to over 100 tanks a month to replace losses from the war and restock the Army's inventory. But Chrysler discovered that it would only be able to increase production up to 40 tanks a month due to the limited supply of tank hull and turret castings from commercial foundries. At that time, there were only four foundries in the U.S. that could produce castings for the M60 tank.

Interestingly, this same problem had been identified by Government and industry as early as 1950. Of those four foundries, only two agreed to help DOD reconstitute the armor inventory and the Government agreed to fund capital investment to the two foundries to expand production of tank castings. Unforeseen by Chrysler, the EPA had recently placed an additional burden on the foundries to meet clean air standards further delaying production. In the end, "it took five years to increase M60A1 production from 30 to 120 per month after the 1973 Middle East War."[7] The lesson learned from the October 1973 War was that increases in tank production would take several years to achieve and that the tank industrial base was incapable of producing large amounts of tanks on short notice.

This lesson was again repeated in 1976 when the decision was made to produce the M1 tank. In this instance, the Army had mothballed the Lima Army Tank Plant (LATP) in Lima, Ohio from 1959 to 1976. Consequently, by the time Chrysler had prepared LATP for tank production, four years had elapsed from the time the Army had made its announcement to produce the M1 to the time that the first M1 rolled off the assembly line.

D. THE M1 ABRAMS TANK PROGRAM

General Dynamics Land Systems Division (GDLS), has been the prime contractor for the M1 since 1976 when the Secretary of the Army selected then Chrysler Corporation's Chrysler Defense Corporation XM1 prototype for full scale engineering development (General Dynamics acquired Chrysler's tank production capability in 1982). A three-year contract was awarded to Chrysler for $196.2 million. The first M1 was completed in 1980 at LATP. Detroit Army Tank Plant (DATP) in Detroit, Michigan began production of the M1 in 1982. During the next three years, 2,374 M1 tanks were

[7]BG(Ret) Philip L. Bolte, "Tank Industrial Base Issues," Personal letter to the researcher, 10 July 1992.

produced at both plants. Production of the basic M1 with a 105mm gun concluded in February 1985; the M1 Improved Product (M1IP) was produced from February 1985 to 1988 for a total production run of 894 tanks. In 1988, production of the M1A1 tank with a 120mm gun began (Figure 1). Further improvements for the M1A1 tank were announced in 1988 consisting of improved armor that incorporated steel encased depleted uranium (DU), which was twice as dense as steel. A total of 4,802 M1A1 tanks were produced, with the latter production models containing DU armor.

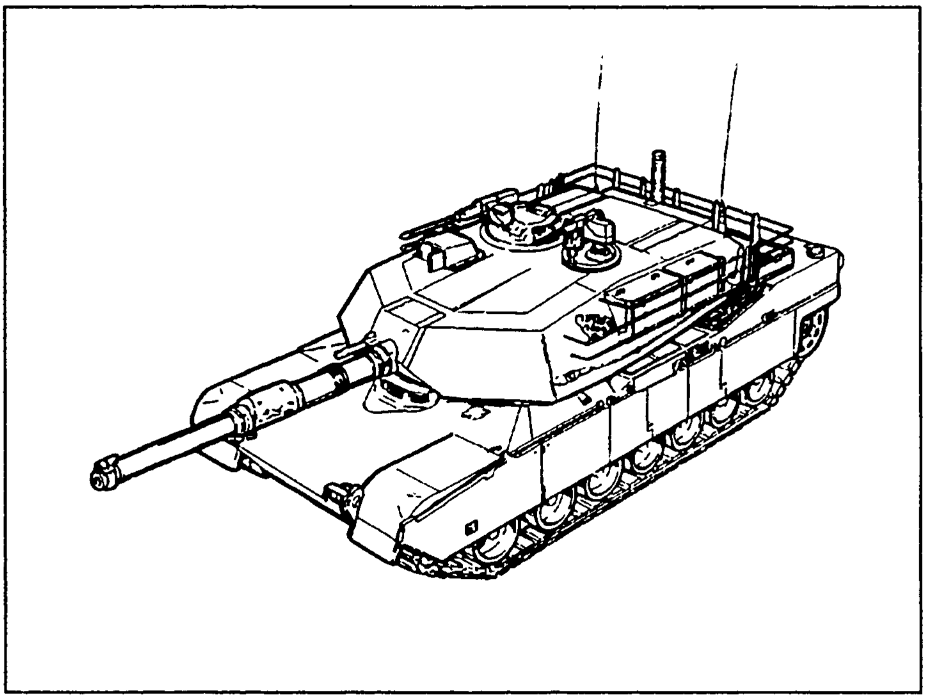


Figure 1 M1A1 Abrams Tank
Source: GDLS.

GDLS has been responsible for incorporating a number of important improvements manufactured by subcontractors and by component producers during the Abrams' production run. The Army's plan for the M1 calls for adding on improvements through block improvements. The initial improvement consisted of improved (Chobham) armor.

The second major block improvement included the 120mm main gun fielded in December 1986. The third improvement for the M1 tank, the Block II tank, was designed to counter the Future Soviet Tank Two (FST2).

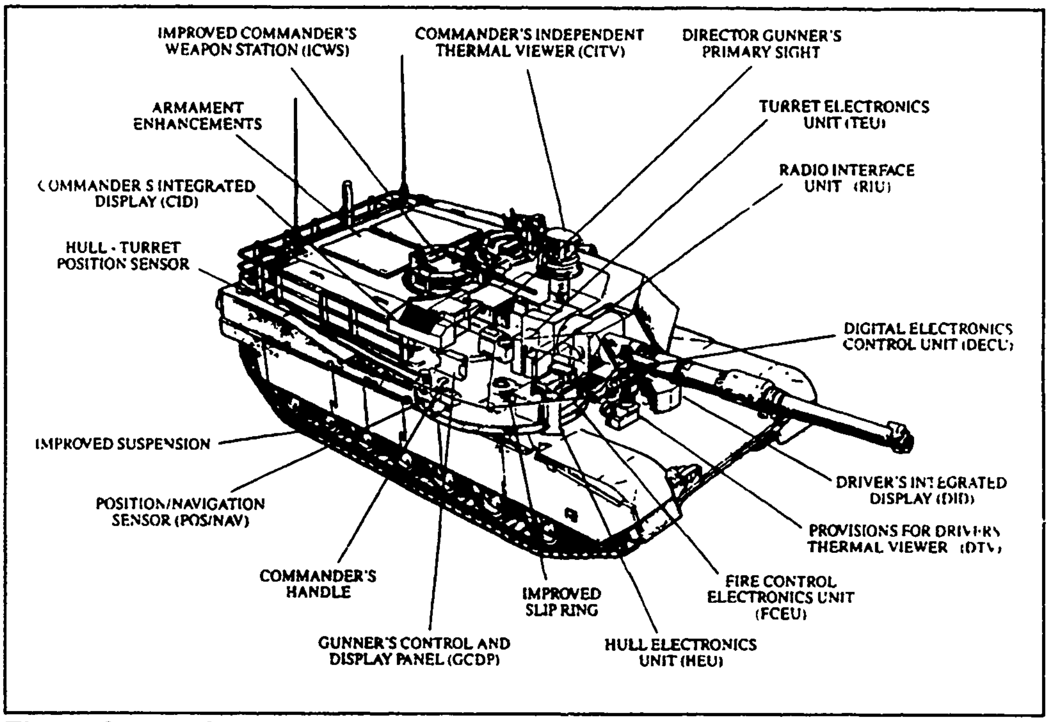


Figure 2 M1A2 Abrams Tank
Source: GDLS.

The Block II tank, better known as the M1A2, incorporates major redesigns to its interior and includes a commander's independent thermal viewer, commander's integrated display, position/navigational unit, driver's thermal viewer and an improved gunner's primary sight. The evolution of the M1 tank, through the M1IP, M1A1 and the M1A2 is documented in Appendix A.

As of January 1993, M1 tank production stood as follows:

- The last M1A1 will be delivered to the U.S. Army in March 1993.

- A total of 62 M1A2s will be produced for the U.S. Army by 1993.

- Congress has appropriated FY93 funds to upgrade 210 M1 105mm tanks to the M1A2 from 1993-1995.

- 550 M1A1 tanks will be coproduced with the Egyptian Government.

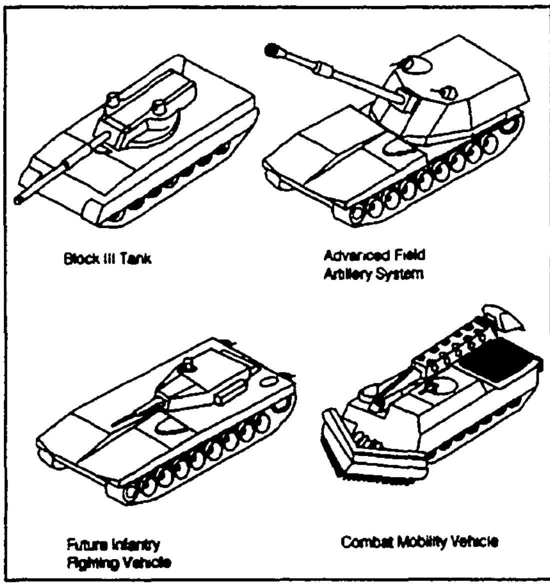
- 700 M1A2 tanks are scheduled for sale to Saudi Arabia.

- 760 M1A2 tanks are scheduled for sale to Kuwait.

The follow-on to the M1A2 has been designated the Block III tank and is part of the Army's Armored Systems Modernization Program (ASM).

E. THE ASM PROGRAM

The ASM concept, initiated in 1980, called for the development of a common chassis for a total of seven heavy and medium armored vehicles as a cost reduction measure. Four of the vehicles: the Block III tank, the Combat Mobility Vehicle (CMV), the Advanced Field Artillery System (AFAS), and Future Infantry Fighting Vehicle (FIFV), share a common heavy chassis (Figure 3). The Line-of-Sight Antitank vehicle (LOSAT) and Future Armored Resupply Vehicle-Ammunition (FARV-A), share a common medium chassis (Figure 4). The last vehicle is the Armored Gun System (AGS) and it has been developed on a light chassis. Program cost for the ASM program in 1991 was $59 billion, not including the AGS.



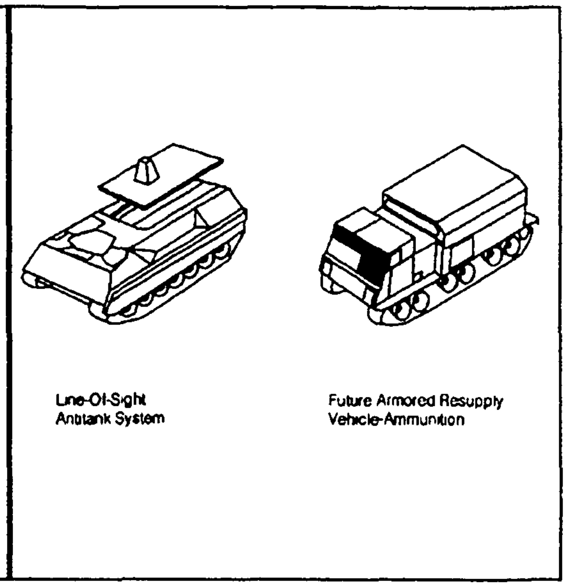


Figure 3 ASM Heavy Chassis Vehicles **Figure 4** ASM Medium Chassis Vehicles
Source: GAO.

Army planning from the close of World War II emphasized the need for combat systems designed to fight against a numerically superior enemy with superior technology. This planning was used by the Army to justify the ASM program. But the breakup of the Warsaw Pact and subsequently the Soviet Union forced DOD and Congress to review the ASM program. The Army, in its revised threat assessment report to justify its mission needs for ASM, did not recognize the diminished Soviet threat in its justification for the ASM program as late as June 1991.

However, a July 1991 Congressional GAO report called the need for the Block III tank into question. It stated that, The Army continues to view the Block III tank as its top priority, even though a projected delay in the fielding of the Future Soviet Tank Three (FST3)-the Soviet Union's future main battle tank, which the Block III will be designed to defeat-appears to make its requirement less urgent. This delay pushes the expected fielding to the middle of the next decade.[8]

The GAO stated in its findings that:

- The Army had not reassessed the need for the ASM program.

- The affordability of the ASM program was questionable.

- The ASM program priorities were inconsistent with the threat.

It further recommended that:

- The Secretary of Defense reassess the ASM program's justification, affordability, and priorities in light of the significant threat changes, projected Army-wide funding shortfalls and the greater need for ASM vehicles other than the Block III tank.

- It also stated that if the 1992 tests demonstrated the viability of electrothermal gun technology, that the Secretary of Defense should direct the Army to evaluate using this technology to upgrade the M1/M1A2 fleet, thereby reducing the need for the Block III tank.

- Finally, GAO stated that Congress should cease additional funding for the ASM program without an accompanying DOD reassessment of the justification and affordability of the ASM program anc the priority of the vehicles within the program.

The FY93 Budget request to Congress reflected the recommendations found in this GAO report and as a result, the ASM program was reorganized and the Block III tank

[8]U.S. General Accounting Office, Report to the Chairman, Subcommittee on Defense, U.S. Senate, *ASM: Program Inconsistent with Current Threat and Budgetary Constraints*, GAO Report GAO/NSIAD-91-254, Washington, D.C.: U.S. Government Printing Office, 1991, p. 3.

canceled. The Army's FY93 Research, Development, Test and Evaluation budget request reflects this threat reassessment and outlines a revised ASM program:

> The program as outlined last year has been restructured significantly. The Block III tank, the Combat Mobility Vehicle and the Future Infantry Vehicle have been deferred indefinitely. The Line-of-Sight Antitank Vehicle weapon system will not go into production as previously planned and will continue in development as a prototype program. The restructured program now gives priority to the Advanced Field Artillery System and the Future Armored Resupply Vehicle-Ammunition.[9]

Current trends indicate that the future of the ASM program appears bleak. In sum, it is unlikely that the Block III tank will be fielded within the next twenty years and in light of the repeated cutbacks in ASM funding during the last months of FY92, the program appears nearly terminated.

F. THE FY93 BUDGET

1. The Army Budget Request to Congress

The Army obtains funding for its armored vehicles through two program elements. The first falls under Title III: Procurement, (Weapons and Tracked Combat Vehicles). The second falls under Title IV: Research, Development, Test and Evaluation, (Research, Development, Test and Evaluation, Army).

a. Weapons and Tracked Combat Vehicles

The Weapons and Tracked Combat Vehicles (WTCV) falls under the procurement appropriation and encompasses tracked combat vehicles and weapons and

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[9]Association of the United States Army, *Army Budget, Fiscal Year 1993: An Analysis*, Arlington, VA: AUSA Institute of Land Warfare, May 1992, p. 46.

other tracked vehicles. Fiscal year 1991 was the last contract for U.S. procurement, with the final new tank delivery due in March 1993. The WTCV appropriation dropped from $1,111,096,000 in FY92 to $921,389,000 in FY93.[10]

b. Research, Development, Test and Evaluation

The Research, Development, Test and Evaluation (RDT&E) appropriation incorporates the resources of Army research, development, test and evaluation involved in the development of weapons and equipment. The RDT&E budget for the Army dropped, in current dollars, from $6,563,000,000 in FY92 to $6,032,860,000 in FY93.[11]

2. ASM/M1 Budget Status

Overall funding trends for armor vehicle procurement is downward similar to the overall defense budget decline. Except for the AGS, armor programs are steadily losing what few budget dollars they have remaining.

a. ASM

The ASM program rose, in current dollars, from $299.8 million in FY92 to $332.3 million in FY93 with initial procurement of the AGS to take place during this

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[10]U.S. Congress, House of Representatives, *Making Appropriations For The Department of Defense For The Fiscal Year Ending September 30, 1993, And For Other Purposes*, Conference Report 102-1015 to Accompany H.R. 5504, 102nd Congress, 2nd Session, 05 October 1992, p. 88.

[11]FY93 Conference Report, p. 120.

time.[12] The initial procurement for the AGS is primarily for tooling. As stated earlier, the Block III was deferred indefinitely with emphasis placed on the AFAS and the FARV-A.

b. M1 Abrams

Congress approved the Army's budget request for M1 tank program management and fielding and the M1 tank modifications for the FY93 appropriation (Table III). In addition, the House and Senate both agreed to fund the upgrade of older M1 tanks to the M1A2 since "no replacement tank program is contemplated for at least 15 years, the United States will lose the existing tank manufacturing industrial base unless action is taken to maintain it."[13] For this reason, the Congress denied the Army's request to rescind the $225 million appropriated in FY92 for the upgrade program.

> The conferees believe the M1 upgrade program as proposed by Congress is consistent with the aims of the Department's new acquisition strategy. Over 40 percent of the existing M1 inventory is comprised of early models which lack the 120mm cannon, heavy armor package, chemical warfare protection, and other improvements found in the newer versions. As is well known, the Army chose to replace first generation tanks with more modern 120mm tanks before the ground war began in Operation Desert Storm.
>
> Moving forward with an upgrade program would increase the overall operational effectiveness of our tank inventory at reasonable cost while preserving the critical skills which are unique to main battle tank production. Given the demise of the Block III tank program, the conferees believe the need for an M1 tank upgrade

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[12]U.S. Congress, House of Representatives, *Department of Defense Appropriations Bill, 1993*, Report 102-627 to Accompany H.R. 5504, 102nd Congress, 2nd Session, 29 June 1992, p. 160.

[13]FY93 House Appropriations Bill, p. 87.

program has clearly increased. Therefore, the conferees reject the proposal to rescind the $225,000,000 slated for the tank upgrade program.[14]

Additionally, it denied the Army from upgrading M1A1s to the M1A2 and included a general provision in the FY93 House Appropriation (Section 9114) which prohibited the use of funds from any tank upgrade program which did not start with the 105mm M1 tank. This upgrade plan continues to be a major source of conflict between DOD and Congress. The final M1 procurement appropriation is contained in Table III.

TABLE III
M1 ABRAMS BUDGET TRENDS

	Fiscal Year 1992 Quantity/$ millions	Fiscal Year 1993 Quantity/$ millions
M1 Abrams	18/106.6	*0/32.4
M1 Abrams mods	0/79.3	**0/25.2
Total	18/185.9	0/57.6

*Annualized support costs.
**Modification kits for older tanks.
Source: FY93 Conference Report.

Congress has provided funding to retrofit M1s to the M1A2, but new tank production should end by March 1993.

3. The FY93 Appropriation

Congress appropriated $161 million to upgrade the oldest M1 tanks to the M1A2. In addition, with the $197.4 million obtained from the sale of tanks in the Army inventory in FY91/92 and the $225 million appropriated in FY92, the way is clear for

[14]FY93 House Appropriations Bill, p. 86.

at least the 1992-1995 time frame, for the retrofit of 210 M1s to the M1A2.[15] The tank industrial base in the near-term seems secure, although the challenge will be to secure the additional three billion dollars required to retrofit the 792 M-1s to the M1A2.

Regardless of what occurs, FY94 will emerge with continued debate on the posture of the tank industrial base. Additionally, in FY94, the defense budget will no longer be protected from the budget fences specified in the 1990 Budget Enforcement Act. Therefore, there will be those in Congress who will want to divert defense funds to domestic and international programs. The likelihood of this happening is high, with the long-term detrimental effects of such a strategy not being felt for many years or until the next conflict.

G. ACQUISITION STRATEGY AND INDUSTRIAL BASE POLICY TODAY

1. DOD/Army Acquisition Strategy

In February 1992, as the U.S. Army continued the drawdown that began with the breakup of the Soviet Union and Warsaw Pact, the Secretary of Defense publicly stated that the DOD acquisition focus would retain an emphasis on research and development because technology was the key to keeping casualties low and winning battles, as evidenced in Desert Storm. He continued to say that a higher reliance would be placed on upgrades and technology insertions in existing platforms followed by full scale production after a thorough test and evaluation period.

[15]FY93 Conference Report, p. 89.

The Secretary of the Army's acquisition strategy follows the logic at the Office of the Secretary of Defense (OSD) level by stating:

> Defense acquisition in the future will be characterized by (1) fewer new system development and production programs, (2) greater reliance on technology insertion through upgrades of existing systems to avoid tactical, logistical and technical obsolescence, and (3) greater use of Advanced Technology Demonstrations (ATDs), the "show me" phase of our science and technology (S&T) program, to validate the maturity and utility of advanced technologies and thereby reduce risk in future acquisition programs.[16]

The upgrades described by the Army Acquisition Executive are system/block upgrades and technology insertion programs. Examples of this in the tank procurement arena are the M1A2/Block II tank and electrothermal gun technology respectively.

This policy will make it more difficult to justify the procurement of new weapon systems. The FY93 DOD procurement budget reflects the new policy by the reduction of new weapon systems purchases and emphasis on upgrades. To commit to a new weapon system, the following criteria will have to be met:

- A clear and verified military need exists.
- The technologies have to be demonstrated, thoroughly tested, and successfully proven for production.
- The production program is cost effective.[17]

The Army's overall acquisition strategy goals can be further subdivided into three areas; modernization strategy, resource allocation strategy, and acquisition strategy.

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[16]Stephen K. Conver, "From The Army Acquisition Executive," *Army Research, Development & Acquisition Bulletin*, July-August 1992, p. 57.

[17]Conver, *RD&A Bulletin*, p. 57.

a. Modernization Strategy

The modernization strategy focuses on long-term technology that creates overmatching capabilities against a projected threat. Formerly, this threat had been the Soviet Union and Warsaw Pact. Now it comprises a number of regional threats with varying capabilities. This strategy chooses to eliminate technological surprises from a potential enemy by requiring continuous modernization. At the same time, this strategy has considered the risks of delaying modernization as a near-term economic measure e.g., the Army's decision to terminate M1A1 production in order to shift funds to the Block III tank resulted in both the M1A1 and Block III being canceled.

A successful modernization strategy should imply that sufficient funding has to be provided to get ideas out of the laboratories and into the user's hands. In reality, the most recent defense budgets reflect a decrease in funds. Modernization strategies are linked to the industrial base through the technological capabilities found at laboratories, factories, and other research and development establishments. They must be protected to preserve the options to modernize in the long-term.

b. Resource Allocation Strategy

This strategy involves funding both the procurement and research and development (R&D) accounts. The Army Senior Acquisition Executive (SAE) stated that the procurement to R&D expenditures ratio has historically ranged between 2.0:1.0 and 3.0:1.0 over the past three decades with an average of 2.5:1.0. That is, $2.50 in procurement is spent for every dollar invested in R&D. For a solid long-term program, the procurement to R&D ratio should be no lower than 2:1. Currently, it stands at

1.25:1 and could go to 1:1 or less in the future.[18] This is due to the new emphasis on technology and DOD's inability to fund large numbers of new production programs.

Again, the resource allocation strategy calls for funding programs that satisfy a strong user need, are executable, and can be approved by OSD and Congress. Savings from Operation and Maintenance accounts, or those savings generated by retiring obsolete equipment and fielding more efficient equipment are permitted to be put back into procurement of replacement equipment. The Army proposed retiring older M1 and 5000 M60 tanks to generate savings from the Operation and Maintenance account in order to fund future tank purchases or the M1 to M1A2 retrofit.

c. Acquisition Strategy

The overall guidance provided by DOD to the Services and the Army is to develop a tailored acquisition strategy for each specific program. Formal procedures are contained in DOD Directive 5000.1, *Defense Acquisition*, which establishes "a disciplined management approach for acquiring systems and materiel that satisfy the operational user's needs." Additionally, DOD Instruction 5000.2, *Defense Acquisition Management Policies and Procedures*, outlines the framework for translating the mission need into,

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[18]Stephen K. Conver, "Shaping the Defense Industrial Base of the Future," Office of the Assistant Secretary of the Army for Research, Development, and Acquisition, Draft working paper, 1992, p. 3.

> ...stable affordable acquisition programs that meet the operational user's needs and can be sustained, given projected resource constraints; and a rigorous event-oriented management process for acquiring quality products....[19]

The instruction also places an emphasis on acquisition planning, improved communications with the users, and stresses risk management from all players in the process. The Army's acquisition strategy is merely a reflection of DOD acquisition strategy.

2. Industrial Base Policy

a. DOD Policy

Critics have described recent industrial base policy as "uncoordinated, incoherent, and ill-conceived."[20] Current DOD policy towards preserving the industrial base is to essentially let market forces do the work. Some DOD industrial base assumptions, based on recent decisions at the OSD level are that:

- Whatever remaining industrial capacity survives during the drawdown is enough to meet future needs.
- Whenever funds become available, industry can quickly respond to rebuild production capacity.
- Defense industries can become commercially viable entities in the hiatus between DOD contract termination and future starts.[21]

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[19]DOD, USD(A), *Department of Defense Instruction 5000.2, Defense Acquisition Management Policies and Procedures*, 23 February 1991.

[20]Blackwell, p. 14.

[21]Don Yockey, "Defense Acquisition," Memorandum from the Under Secretary of Defense for Acquisition, 20 May 1992.

Recent comments by the Deputy Secretary of Defense reaffirm the above assumptions since he believes that "future wars will be deterred, end quickly, or be preceded by so much warning that there will be plenty of time for reconstitution."[22] He bases his rationale on dual-use technologies, promotion of civil-military integration, and applications of procedures consistent with commercial practices coupled with a free market economy.

With respect to the tank industrial base, the Under Secretary of Defense specifically stated in his acquisition memorandum to the Services and before Congress that "there are enough tanks available now to meet any perceived contingency, and there is enough time to reconstitute the tank industrial base if a global threat emerges. Therefore, tank production will cease as planned."[23]

The overall philosophy of DOD, thus far, has been not to interfere with the operation of the free market with regard to the industrial base. This policy stance has caused contractors to leave the defense business permanently over the last several years. It may save dollars in the short-term but the long-term implications for industrial base preservation could be devastating.

b. Contractor/Industry Policy

The industries that make up the industrial base face great uncertainty about the future. Therefore, there are few insights on what production should be

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[22]John W. McDonald, *U.S. Defense Industrial Base Preparedness*, Arlington, VA: Association of the United States Army Landpower Essay No. 92-1, February 1992.

[23]Yockey, 20 May 92.

maintained for each sector of the defense industrial base. There also exists a glut of capital equipment and production capacity due to the defense buildup of the 1980s. Maintenance and costs to hold on to these facilities are enormous. The uncertainty due to a lack of coherent national industrial base policy is causing industry to exhibit reluctance in making capital investments for modernization in future DOD contracts. Options for foreign military sales are made difficult by competition from government-backed European and Pacific nation consortiums along with a lack of Government support and bureaucratic obstacles here in the U.S.

Additionally, the problems generated by the declining defense budget are exacerbated by the regulations and practices associated with doing business with DOD. Furthermore, "these practices increase the cost of military systems by adding as much as 25 to 50 percent to unit costs and procurement time."[24] Adopting commercial standards through actions such as converting military specifications to non-governmental standards, adopting European vendor standards (ISO 9000) for supplier accreditation and adopting Society of Automotive Engineers (SAE) standards, are some of the ways that have been suggested to reduce costly reviews and audits mandated by current Government regulations and reduce overhead and duplication of effort.

[24]U.S. Congress, Structure of the Industrial Base Panel of the Committee on Armed Services, House of Representatives, *Future of the Defense Industrial Base*, Report No. 10, 102nd Congress, 2nd Session, 07 April 1992, p. 13.

(1) Technical Data Rights. Technical Data Rights continue to sour relations between Government and the tank industry ultimately stifling research, development and innovation. Industry leaders would like to see the balance of technical data rights being shifted from the Government back to the industry.

(2) Cost Accounting Standards. Government Cost ˙ccounting Standards add excess overhead to companies doing business with the Government. These obstacles force contractors to establish additional administrative structures to handle Government unique requirements further discouraging business with DOD and ultimately erodes the defense industrial base.

(3) Federal Acquisition Regulation (FAR). The FAR does not allow contractors to use Government-owned equipment and tooling left in their facilities during DOD contract breaks for commercial ventures. Critics of these regulations believe allowing contractors to utilize Government-owned equipment during DOD contract production breaks will promote dual-use technologies and most importantly, reduce idle manufacturing time.

H. OTHER INDUSTRIAL BASE ISSUES

The following areas have been suggested as possible alternatives for maintaining a viable indus'᾽ₓᵣ base for the future. Although these are programs generally in the conceptual stagɩ, ihey have the potential for expanding the options for preserving the tank industrial base. These areas could affect the way DOD, congressional and industry decisionmakers approach industrial base issues in the future.

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1. Conversion

Congress has recently addressed the issue of defense conversion in the context of a broad plan for the national economy and the structure of the nation's defense.[25] This is generally addressed in the context of finding training and employment for workers displaced by reductions in the defense industrial base. Defense companies have not been successful in moving from the controlled and specialized environment of defense acquisition to the commercial sector unless they are engaged both in defense and commercial ventures. If segments of the tank industrial base undergo conversion in the future, elements of the tank industrial base must be able to successfully transition from the defense sector to the commercial sector. If so, they must also be willing and capable to return to tank production and component manufacture when needed.

2. Reconstitution

The debate on reconstitution centers on whether defense industries can reconstitute themselves after a major downsizing. Since the tank industrial base, along with the defense sector in general, is still undergoing restructuring as part of the defense drawdown, data are still lacking to assess this issue from a restructured tank industrial base.

3. Dual-Use Technology

The dual-use technology concept for both military and civilian applications is a potentially viable option for preserving the tank industrial base, especially in

[25] U.S. Congress, *Future of the Defense Industrial Base*, p. 4.

electronics/optics and propulsion systems. However, military specifications and military standards requirements must be overcome to make dual-use technologies affordable.

4. Flexible Manufacturing

There is potential, with the application of computer integrated flexible manufacturing, to produce multiple systems and preserve the manufacturing base at LATP. Flexible manufacturing processes can be adapted to produce more than one type of item on an assembly line. This makes the production of a smaller number or each type of item more efficient and reduces reliance on economies of scale. For tank production, there is potential for employing flexible manufacturing processes at LATP.

5. Foreign Investment in U.S. Tank Production Capabilities

In the past, there has been concern for the level of investment of U.S. defense firms by foreign entities. Roadwheel production is already controlled by an Israeli corporation and Allison Transmission Division (ATD), the Abrams transmission manufacturer, was sold to a German corporation in January 1993. These two examples seem to show that the level of foreign investment in U.S. tank production is not a major concern to decisionmakers. Furthermore, it appears that governmental regulations monitoring foreign investment in U.S. defense firms are not being enforced.[26]

Increasing levels of investment by foreign firms does not necessarily make U.S. defense industry vulnerable to foreign dependency. In fact, it may be an alternative for preserving the tank industrial base if closely monitored by the Government.

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[26]Michael Sperling, "U.S. Congressman Questions GM Sale," *Defense News*, 11-17 January 1993, p. 25.

In sum, greater investment by foreign firms in U.S. defense production is increasing and a clear policy governing foreign ownership is not in place or being enforced so that industry can maintain future production capability.

6. Original Equipment Manufacturers and Army Depots

This issue involves the teardown of older tanks in preparation for remanufacture to the M1A2. Teardown can be conducted by the Original Equipment Manufacturer (OEM) or at Army depots. The tradeoff between OEM and depot arises because if all work is done at OEM, then the industrial base is preserved through an ongoing reconversion/teardown program. Meanwhile, the depots remain underutilized and could eventually be closed, eliminating any future capability for tank overhauls and major maintenance. On the opposite end of the spectrum, allocating all work to depot activities utilizes the depots to maximum capability but takes away work from the OEM, eroding the tank industrial base in the long-term.

This issue will most likely be resolved now that depots are being required to compete for work against civilian contractors through full and open competition. The source selection process will result in selection of an OEM or depot activity that can provide the best value to the Government.

I. CURRENT STATE AND STRUCTURE OF THE TANK INDUSTRY

The tank industrial base has evolved into a complex structure involving several thousand contractors, subcontractors and second- and third-tier subcontractors.

1. Components of the Tank Industrial Base

The Abrams tank requires one prime contractor and five major subcontractors, broken down by the following management/system engineering classifications or industrial segments:

- Prime Contractor.
- Electronic and optical component manufacturers.
- Complex machining operations.
- Propulsion system manufacturers: engine and transmission.
- Basic material manufacturers: steel and depleted uranium.
- Weapon manufacturers: 120mm cannon and mount.

Production of the Abrams tank is accomplished by GDLS, which operates one plant assembly facility at LATP, a complex machining facility in Scranton, Pennsylvania and an electronics/optical facility in Sterling Heights, Michigan. Primary propulsion production is managed by Textron Lycoming which operates the Stratford Army Engine Plant (SAEP) in Stratford, Connecticut. Allison Corporation manufactures the transmission for the Abrams at the Allison Transmission Division (ATD) in Indianapolis, Indiana. Basic materials consists of large cast steel, armored steel plate, and depleted uranium production. Only two major producers, Atchison Casting Corporation in Atchison, Kansas, along with the newly reopened Birdsboro foundry in Philadelphia, Pennsylvania are capable of producing large castings for the Abrams. The 120mm gun and mount are produced at Watervliet and Rock Island Arsenals. Table IV presents the number of key manufacturers and suppliers for the Abrams tank.[27] A description and analysis of tank subcontractors by industrial segment is contained in Chapter V.

TABLE IV
M1 ABRAMS INDUSTRIAL BASE

Item	Number of Manufacturers
Electronics/Optics	12
Complex Machining	03
Propulsion	10
Basic Materials	03
Weapons	02

Source: Gutmanis.

2. Specialized Equipment Requirements for the Abrams Tank

The Abrams tank is a complex piece of equipment employing many scientific disciplines and difficult manufacturing processes. Therefore, Abrams tank production requires a number of unique processes and specialized equipment such as special armor and depleted uranium production. However, some of the equipment and technologies associated with the equipment may be used in the manufacture of other industrial products. Likewise, some commercial technologies and processes may be transferred from other manufacturing uses to Abrams production. But transfer of such equipment from other uses to Abrams production is costly and time consuming.

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[27]Ivars Gutmanis, *Research and Development, Engineering and Production of Abrams Tank and Bradley Fighting Vehicle System Under Reduced Funding for the U.S. Industrial Base*, Report prepared for the U.S. Congress, Office of Technology Assessment, International Security and Commerce, Washington, D.C.: Sterling Hobe Foundation, October 1991, p. 19.

3. Depleted Uranium Facility

The Department of Energy (DOE) Depleted Uranium (DU) facility in Idaho Falls, Idaho, will cease operations if tank production for the Army is terminated. It is the only facility in the U.S. capable of producing DU armor for the Abrams tank and penetrators for the 120mm sabot round used with the tank's cannon. This will take place because tanks scheduled for Foreign Military Sales (FMS) will not be equipped with DU armor and the last new DU tank for the U.S. Army is scheduled for completion in March 1993. The M1A2 upgrade plan in the FY93 DOD budget will keep the plant open through 1995.

J. OPTIONS AVAILABLE TO DOD, CONGRESS AND INDUSTRY

1. Policy Options

The following three options to sustain the tank industrial base are among several that DOD, Congress, and industry have proposed and are evaluating as of this writing:

a. OPTION ONE: The Army should mothball the Lima, Ohio tank plant after the last Abrams is built.

This option is based on a strategy of sacrificing n ar-term procurement in order to maintain viable research and development programs for the future. This includes a complete layaway of LATP, extensive layoffs, and complete termination of production. This option also creates a loss of conceptual, engineering and management expertise associated with tank production but not necessarily tank design. As a result, future starts would result in significant shifts in the learning curve. Under mobilization conditions, it is estimated that it would take at least three or more years to bring production from 0 to 120 tanks per month. GDLS makes up about ten percent of General Dynamics' business and the M1 is the primary vehicle manufactured by GDLS. Total plant closure would not make it economically viable for General Dynamics to own GDLS even though LATP is Government-owned. This closure plan would also be catastrophic to second- and third-tier subcontractors, with many of these going out of business or shifting their business to the commercial sector.

b. OPTION TWO: The Army should reduce production to the minimum production rate that will keep the factory operational until the factory retools for the next generation tank.

This option again is based on a strategy of sacrificing near-term procurement in order to maintain viable research and development programs for the future. This would include dropping production from the current thirty tanks per month to twenty per month. This would maintain a production process, critical equipment and skills and would provide for an orderly expansion of production in a national emergency. There would be some loss of skilled workers and engineers, but the learning curve would remain stable until production expanded and a dip would be experienced as new workers and engineers were hired.

Producing at such low numbers could become inefficient and significantly raise unit costs. This situation is aggravated at subcontractor level and many would not be willing to produce at less than reasonable per unit costs. Current foreign military sales contracts are insufficient to sustain production at rational per unit costs.

c. ***OPTION THREE: The Army should complete production of the M1A1 tank and then use the factory to retrofit/upgrade older model tanks to the M1A2.***

This course of action bridges the M1 to the Block III by incorporating emerging technologies into the Block II. The retrofit program consists of taking an M1 or M1A1 tank and converting it to an M1A2. The process is less costly than building a brand new M1A2 tank because rather than build a completely new tank, only the turret of the tank is newly built while the hull and propulsion system of the M1A2 come from a refurbished M1 hull and engine. Overall, the cost to convert an older Abrams to an M1A2 is roughly two-thirds the cost of building a brand new M1A2 tank.[28] Specific costs, under different configurations, for the M1A2 reconversion program are contained in Appendix C.

The retrofit process includes the following: (1) older tanks are shipped to a depot where the hull is separated from the turret; (2) common or reusable components such as the engine, transmission and hull are kept, while the turrets are disassembled, demilitarized, and scrapped; (3) hulls and other common components are overhauled and sent to LATP for reassembly including M1A2 particular component

[28]Gary R. Diaz and Donald L. Gilleland, "The M1A2 Conversion Programme," *Military Technology*, February 1992, p. 1.

upgrades; and (4) the refurbished hulls are then married to newly built M1A2 turrets which would include the latest upgrades.

This option would maintain the industrial base and workforce at all levels while maintaining relatively state-of-the-art equipment in the field. The exception to this is that the Stratford Army Engine Plant (SAEP) and the Allison Transmission Division (ATD) would partially shut down except for limited spare parts production.

Full funding for this course of action has been approved for 210 tanks in the FY93 budget. But the three billion dollars needed to reconvert the remaining 792 tanks between 1996-1999 may be difficult to obtain in the current budget climate. This course of action would keep tank production at current levels and incorporate depot services from Anniston Army Depot and Red River Army depot as well. In conclusion, this option maintains the industrial base while providing the armor force with technologically superior weapon systems.

III. THE TANK INDUSTRIAL BASE WORKFORCE

A. INTRODUCTION

Tank production requires specialized skills in many disciplines, found nowhere in the commercial sector. This chapter will examine the effects of the three options suggested for sustaining the unique workforce associated with and necessary for a tank industrial base.

B. WORKFORCE ISSUES

The major issues affecting the tank industrial base workforce are worker training and certification. However, other considerations such as effects on the depleted uranium facility workforce will also be examined.

1. Training and Certification

The Lima Army Tank Plant (LATP) and General Dynamics-Land Systems Division (GDLS) employ over 8000 workers and engineers conducting research, design, development and operation of specialized tank manufacturing equipment as found in Table V.

TABLE V
SPECIALIZED TANK MANUFACTURING EQUIPMENT

• Computer and direct numerical controls (CNC)
• Robotics welding machinery
• Turret machinery equipment
• Plasma armor plate cutting equipment
• Complex machinery systems
• Special DU armor fabrication equipment
• Large aluminum casting and forging equipment
• Advanced optical coating machinery
• Very large steel casting equipment

Source: GDLS.

This equipment, in turn, requires specialized skills associated with tank production that can only be found at LATP and GDLS. In their 1991 and 1992 closure studies, Tank-Automotive Command (TACOM) and GDLS identified and classified these critical personnel skills. They were: (1) that personnel are highly trained and experienced, (2) they require a long training period, and (3) that there exists a shortage of those skills in industry.

The specific critical skills that were identified included:

- Certified ballistic welders
- Computer numerical control personnel: programmers, troubleshooters, repairmen, and machine operators
- Direct numerical control personnel: programmers, troubleshooters, repairmen, and machine operators
- Dye penetrant and magnetic particle inspectors
- Precision tool engineers and other special purpose personnel

Many of these personnel, including subcontractor personnel, are required to have a minimum of five years experience in other related areas of expertise, plus an additional two years of training in specific Abrams manufacturing skills. For example, of the workforce at LATP, there are 600 certified ballistic welders on the production line. The training cycle for a ballistic welder is a lengthy and difficult process.

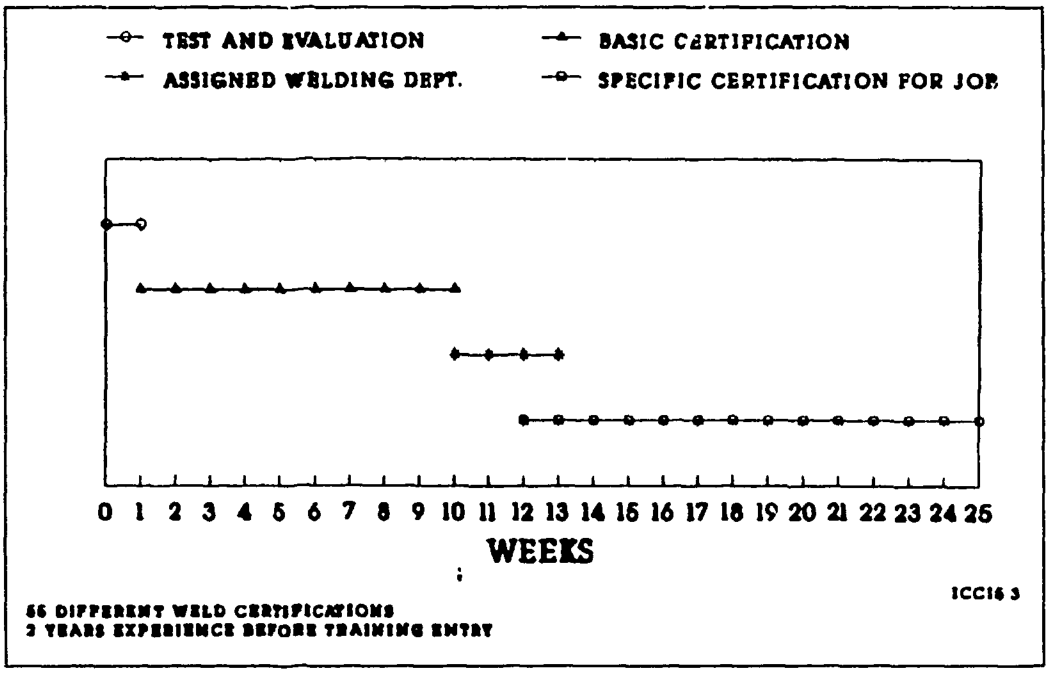

Figure 5 Ballistic Welder Certification Cycle
Source: TACOM.

As Figure 5 shows, GDLS starts with journeyman welders with a minimum of two years experience and tests them for one week. The journeyman welder then attends a nine week certification course plus thirteen or more weeks of ballistic qualification. Even after this process, not all ballistic welders attain the required certification to work on the tank assembly line.

From the research and development aspect of tank manufacture, the engineers who make up the design staff at GDLS must have expertise in several areas to include metalworking, electrical engineering, optics, advanced materials and ballistics. Much of the design staff has had previous experience in tank design with "many senior engineers and managers associated with M1 development and production having cut their teeth on earlier tank programs."[29] The Abrams workforce has considerable experience behind it and the efforts required to train it to proficiency have been lengthy. In sum, the cost of human capital at LATP and GDLS has been high.

2. The Depleted Uranium Facility

Should the Depleted Uranium (DU) facility close given production termination, future production restarts for DU armor will be made more difficult over time as labor skills degrade and disappear. Certification for DU workers requires permits from the Nuclear Regulatory Commission (NRC), Occupational Safety and Health Administration (OSHA), and the Environmental Protection Agency (EPA). Worker certification is a lengthy process and for these reasons, it is estimated that if the DU facility is closed, it would take 24-42 months to start up DU production for tank armor.

3. Additional Workforce Considerations

Additional considerations that also impact the effects of the three options on the workforce is the impact of the aging workforce in industry overall. Compounding

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[29]BG(Ret) Philip L. Bolte, "Budget Cuts: Effects On the Industrial Base," Part I of III Articles, *National Defense*, April 1991, p. 33.

the problems associated with maintaining the experience involved in tank production, "a skilled but aging workforce will leave the defense sector over the next ten years, with or without plant closings."[30] This aging of the workforce must be considered when evaluating the options to layoff workers. Traditionally, it has been the senior worker who supervises the junior worker and assimilates or mentors him into the system. Loss of this talent without an influx of new replacements could be potentially disastrous for future tank production.

C. WORKFORCE ANALYSIS

The following is an analysis of the potential effects of each of the three options available to DOD, Congress and industry upon the tank industrial base workforce.

1. OPTION ONE: The Army should mothball the Lima, Ohio tank plant after the last Abrams tank is built.

As stated earlier, this option is based on a strategy of sacrificing near-term procurement in order to maintain a viable research and development program for future tank programs. This includes a complete layaway of LATP, extensive employee layoffs and termination of tank production. TACOM defines layaway as the process of retaining

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[30]Association of the United States Army, "Industrial Base," Statement by General Jack N. Merritt, U.S. Army (Ret), before the Panel on Structure of the U.S. Defense Industrial Base, House Armed Services Committee, U.S. House of Representatives, 102nd Congress, 19 February 1992, p. 7.

and storing industrial facilities that are no longer required to support current production but may be required to support production at a later date.[31]

As shown in Table VI, the TACOM closure studies estimate that production termination would eliminate over 4000 personnel specifically at the following locations:

TABLE VI
EMPLOYEE REDUCTIONS GIVEN PRODUCTION TERMINATION

Location	Personnel Losses
Lima Army Tank Plant	2191
Detroit Army Tank Plant	481
Scranton Complex Machining Plant	381
Sterling Heights Electro/Optical Plant	313
Central Office Complex/GDLS Headquarters	702
Total	4068

Source: TACOM.

An additional 5048 employees would lose jobs in the primary vendor locations at Watervliet and Rock Island Arsenals, Stratford Army Engine Plant (SAEP), and Allison Transmission Division (ATD). The Government is contractually liable for human resource separation costs at all the above locations. Human resource costs are defined as all costs associated with separation of contractor personnel including separation pay, health care, supplemental benefits, group insurance, pensions and dental care. From a workforce perspective, the Government can expect to pay out at least

[31]U.S. Army Tank-Automotive Command, *Abrams Program Closure Study*, Warren, MI: Unpublished Slides, September 1990, Slide ICC 3.

$96.3 million in human resource separation costs for total production termination.[32] For example, according to the August 1991 *Abrams Program Closure Study*, human resource costs at LATP would be $37.4 million in 1991 budget dollars.

a. Advantages

Because of the high costs of eliminating the tank production workforce, there are few advantages to terminating production of this unique product. But given the current defense budget climate, a plethora of fielded systems, and the current technological superiority of the M1A1 over other tanks, there is little justification in supporting a workforce that will continue to manufacture excess systems.

b. Disadvantages

Because the long training period required to prepare a GDLS employee for tank production, closure of LATP will force the employee to seek employment outside his field of expertise. Not only will this degrade his skills in the long-term, but in the event of a production restart in the future, he will require a lengthy retraining and certification period. There is also no guarantee that a worker will return to work for tank production once established in another job.

This option also affects senior engineers and managers at LATP and GDLS. This is critical to GDLS since the only product it manufactures is the M1-series tank. "The expertise of tank designing is perhaps the most critical, yet most difficult to

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[32]U.S. Army Tank-Automotive Command, *Abrams Program Closure Study (Austere)*, Warren, MI: Unpublished Slides, 13 August 1991, Slide VC 10.

define, potential loss faced by stopping tank production."[33] The tank, being a unique product, is a result of many years of design experience which includes a talent to mesh many conflicting requirements into one properly system-engineered weapon system. The skills lost would be hard to replace.

As GDLS management and the workforce become familiar with overall production techniques, the increase in production efficiency and quality is reflected in the learning curve. General Dynamics-Land Systems Division has collected monthly data on hours per unit from the Abrams' inception. For the first 2000 M1s, the learning rate based on a regression analysis reflected a 90.2 percent learning curve for both LATP and DATP.[34] General Dynamics also stated that they have not developed a learning curve for the M1A1 as it would be misleading since there was a multiyear contract and an Industrial Productivity Improvement Program with funding provided for improvements. Since the funds were one time investments, the curves generated would not be representative of normal learning; "however, some slight improvement can be attributed to the continuation of normal learning."[35]

The learning curve reflects an increase in production efficiency and quality over time and a concurrent cost decrease given an uninterrupted production run. The Abrams program has thus far shown that, "as M1 production proceeded, deficiencies

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[33]BG(Ret) Philip L. Bolte, "Tank Industrial Base Issues," Personal letter to the researcher, 10 July 1992, p. 4.

[34]M.A. Puzzuoli, Memorandum/facsimile to the researcher from Manager, Quality Programs, General Dynamics-Land Systems Division, 08 January 1993, p. 4.

[35]Puzzuoli, p. 4.

decreased, but as major changes were introduced there was a sudden increase in deficiencies. This was followed by a decrease as management and workers became more familiar with the changes."[36]

Termination of production could cause a major shift in the learning curve with significant production efficiency and cost reduction lost. "Among defense programs, this factor is unique in the area of development and production, because there is no equivalent commercial activity that might serve as a peacetime storehouse for the talent."[37]

In sum, TACOM and GDLS represent a vast sum of knowledge based on experience that would be lost by going to layaway.

c. *Conclusions for Option One*

From a workforce perspective, the effects of total production termination are potentially the most devastating to preserving the tank industrial base. The loss of over 9000 jobs, from the welder to the senior engineer, will not only be the immediate effect felt in industry. The projected loss of personnel skills, qualifications, and experience along with the decrease in production efficiency and quality would occur fairly rapidly. This would have a significant effect if a requirement to design and produce a new tank occurred in a few years. Future costs to retrain a workforce would

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[36]BG(Ret) Philip L. Bolte, "Budget Cuts: Effects On the Industrial Base," Part II of III Articles, *National Defense*, May/June 91, p. 8.

[37]BG(Ret) Philip L. Bolte, "Budget Cuts: Effects On the Industrial Base," Part I of III Articles, *National Defense*, April 1992, p. 33.

be high as well. For example, if the total layaway occurred for a period of ten years, a large portion of the $1.4 billion to start production of the Block III tank would be attributed to retraining the workforce.[38] The long term effects for future tank design and production are potentially damaging without a core of skilled workers, engineers and managers.

2. **OPTION TWO: The Army should reduce production to the minimum production rate that will keep the plant operational until the plant retools for the next generation tank.**

This option is based on a trickle production rate which is defined as a "minimum sustaining rate that maintains a production process, critical equipment, skills, and provides for an orderly expansion to full-rate production in an emergency."[39] This option drops production of the M1A1 tank or reconversions to the M1A2 from a current thirty tanks per month to a low of ten per month. In all trickle rates except at thirty per month, workers will be laid off as reflected in Table VII. This table shows the employee losses and costs associated with varying levels of production.

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[38]Puzzuoli, p. 2.

[39]TACOM, *Abrams Program Closure Study*, Slide ICC 3.

TABLE VII
TRICKLE RATE PRODUCTION EMPLOYEE LOSSES AND COSTS

	30/month	20/month	15/month	10/month
LATP	0	235	587	1053
Scranton	0	47	111	197
Sterling	0	26	68	146
Central Office Complex	0	31	64	338
Total Personnel	0	339	830	1734
Human Resources Costs (millions)	$16.6	$24.6	$39.1	$64.7

Source: TACOM.

a. Advantages

The advantages of maintaining a trickle rate of ten tanks per month is that a warm base would be maintained which would retain an active core workforce in tank production. This core force can be used in an emergency to smooth the assimilation of rehired and new personnel. This core also serves as the basis for a rejuvenated workforce should a peacetime need for expansion arise. The framework for experience and certification is retained by maintaining a trickle production rate.

b. Disadvantages

The loss of skilled workers at all rates excluding the thirty per month production rate could be critical in a full mobilization scenario or under surge conditions given a lower production rate. To bring in new workers under emergency conditions, train, recertify, and give them the necessary experience on the production line, would take a minimum of thirty-six months before a surge rate of 120 tanks per month could be achieved.[40] It is likely that this surge would initially cause a drop in production efficiency and per unit cost increase as new processes were learned or relearned.

c. Conclusions for Option Two

This option is dependent on the trickle production rate selected. The lower the production rate, the more skilled workers that will be lost and the higher the costs associated with rehiring and training them in the event of a production surge. A rate closer to thirty per month would retain more skills and experience for the future while allowing for a more rapid production increase in the case of surge or industrial mobilization.

3. OPTION THREE: The Army should complete production of the M1A1 tank and then use the factory to retrofit/upgrade older model tanks to the M1A2 tank.

As stated earlier, this course of action bridges the M1 to the Block III tank by incorporating emerging technologies into the Block II. This retrofit will require the Stratford Army Engine Plant (SAEP) and Allison Transmission Division (ATD) to reduce operations. Therefore there would be layoffs at these two facilities but production would remain between twenty to thirty tanks per month.

a. Advantages

An uninterrupted production run not only enables a skilled workforce to remain in place, but best preserves the human skills necessary to build a tank. The

[40]TACOM, *Abrams Program Closure Study*, Slide ICC 19.2.

experience gained by management, engineers, and workers on the M1A1 design and production cycle should carry over to the M1A2 program without a degradation of skills due to a break in production. Because the interior design and technology incorporated into the M1A2 is unlike that of the M1A1, one can expect a change in the learning curve as the workforce learns to produce the M1A2. Compared to Option One and Option Two, this change would not be as pronounced. One can expect product quality to increase and production costs to decrease rapidly with the first few tanks off the production line.

b. *Disadvantages*

The disadvantages of this option are marginal because the workforce involved in producing the M1A1 tank would remain in place except at SAEP and ATD as mentioned earlier. Some workers would be lost at both facilities but a smaller workforce would still remain at these two facilities to continue limited spares and repair parts production.

c. *Conclusions for Option Three*

In terms of human capital, this option seeks to establish the foundation necessary to preserve the tank industrial base for the long-term. It allows for better management of the tank industrial base workforce given a future crisis requiring a surge or mobilization situation and allows for a smoother transition to future new tank design and production.

D. SUMMARY

The option that best preserves the tank industrial base from the workforce perspective is Option Three. Option Three, with the exceptions made for SAEP and ATD, enables the workforce to produce an upgraded tank and allows for the transition in production from the M1A1 to the M1A2 to be made under peacetime conditions. It also sets the stage for future main battle tank production by maintaining a skilled and experienced workforce.

Option Two is the next best plan because much of the workforce is retained depending on the selected production rate. Thirty tanks per month would be the optimal rate in order to maintain the entire workforce. Any rate less than thirty per month would result in a loss of skills in the industry.

The least desirable option would be to terminate production as described in Option One. The loss of the skills and experience from management to the production worker would be potentially damaging in the event of a national emergency requiring surge or industrial mobilization or even in the event of a peacetime production restart.

In conclusion, terminating production would be the most damaging to the workforce involved in tank design and production, while retrofitting the older tanks to the M1A2 would best insure retention of the experience and skills garnered from the last sixteen years of M1 tank production.

IV. COSTS

A. INTRODUCTION

The costs involved to execute any of the options presented are a major factor to consider, especially in the current budget climate and overall drawdown occurring in the Department of Defense (DOD). This chapter will analyze the costs involved in executing the three options and their effects on preserving the tank industrial base.

B. COST ANALYSIS FACTORS

In 1989, the Army directed Tank-Automotive Command (TACOM) to conduct a closure study for the Detroit Army Tank Plant (DATP). DATP was subsequently directed to cease production in September 1991 as overall tank production was dropped. In 1990, the Army directed TACOM to conduct a closure study for Lima Army Tank Plant (LATP), which was released in August 1991. A revised study with modified cost estimates was released in April 1992.

The scope of these studies included options to (1) lay away the industrial facilities at LATP and satellite facilities for future use, (2) sustain a trickle production rate that would maintain the production process, critical equipment and skills, and would establish a framework for orderly expansion of production in an emergency, and (3) conduct retrofit of older M1 tanks to the M1A2. These cost estimates were formulated by

TACOM, General Dynamics-Land Systems Division (GDLS), and the Department of Energy (DOE).

1. Assumptions

During the course of these studies, several assumptions were made that would be the basis for the costs presented. They were,

- Restoration of all facilities would be to Occupational Health and Safety Administration (OSHA) and Environmental Protection Agency (EPA) standards.
- The trickle production rate would be twenty tanks per month.
- M1/M1A1 to M1A2 conversions would be twenty tanks per month.
- Contractors would maintain spares production when tank production ceased.
- Vendors/subcontractors that would not or could not produce at twenty tanks per month would be replaced.
- Equipment would be laid away using best commercial practices.
- A cold base or laid away facility would impact future startup costs for the Block III tank or Future Main Battle Tank (FMBT).
- Block III production would start in the fourth quarter of FY01.

2. Other Cost Considerations

When presenting tank per unit costs, a number of variables impact vehicle costs. Variables that must be considered include multiyear contract scenario versus annual production contracts, rates in effect at the time of production, total contract production, learning rates applied to smaller quantities over shorter or longer durations, inflation, and the cost of training, support, spares, and warranty considerations.[41] Foreign sales of the M1A2 are impacted by configuration changes unique to each country in terms of radios, communication equipment, changes to equipment to accommodate language differences, and hardware provided by the purchasing country for installation in the tank.

Questions comparing the per unit cost of a newly-built M1A2 with that of an M1 reconverted into an M1A2 tank focus on the work breakdown structure. Will GDLS perform all work for teardown or will the Government perform the work at the depots prior to GDLS assembly and test; will original components be refurbished, used in the original as is condition, or replaced with new components; and what level of testing should also be required?[42] Current estimates of specific per unit costs for the converted tanks and production tanks are contained in Appendix C.

3. Facilities

Abrams production is keyed on a number of facilities excluding subcontractors. The following facilities represented the main production base for the Abrams tank and consequently were the focus of the cost analysis.

a. General Dynamics-Land Systems Division

As described earlier, GDLS includes a number of facilities. They are the Central Office Complex (COC) located in Sterling Heights, Michigan, the Scranton

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[41]M.A. Puzzuoli, Memorandum/facsimile to the researcher from Manager, Quality Programs, General Dynamics-Land Systems Division 28 January 1993, p. 1.

[42]Puzzuoli, p. 2.

complex machining and metalworking plant in Scranton, Pennsylvania, and the Sterling Heights electro/optical facility in Sterling Heights, Michigan. The COC is GDLS headquarters, located near TACOM headquarters. Sterling Heights manufactures electronic components, sighting equipment, and wiring harnesses for the tank.

b. Detroit Army Tank Plant

The Detroit Army Tank Plant (DATP) ceased tank production in late 1991. A workforce of 480 employees is being retained at DATP and will continue to conduct complex machining operations and some component manufacturing until the Abrams production run is completed. According to GDLS, the plant machines various components for vehicle assembly and produces 50 percent of Abrams production gun mounts, with Rock Island Arsenal producing the remaining gun mounts. Currently, the Government requires GDLS to maintain an in-house surge capacity of 90 per month for components and 45 per month for gun mounts at DATP.[43]

c. Lima Army Tank Plant

Lima Army Tank Plant (LATP) is the current and future core facility for Abrams tank production. Completely rebuilt in the late 1970s for initial M1 tank production, GDLS has invested over $400 million in making it a state-of-art assembly line employing over 2200 people.

[43]Puzzuoli, p. 3.

d. Allison Transmission Division

Allison Transmission Division (ATD), a division of General Motors Corporation, produces the Abrams X1100 transmission. Located in Indianapolis, Indiana, the facility employs a total of 5700 employees with 800 workers dedicated to X1100 production. ATD has about 85 percent of the world's capacity in transmission manufacture.

Current transmission design has built-in flexibility for use with diesel or gas turbine engines. ATD continually undertakes research, development, and engineering for X1100 transmissions, resulting in rapid technological advances in electronics and metal used in the transmission.

e. Stratford Army Engine Plant

Textron Lycoming is the producer of the AGT1500 gas turbine engine used on the Abrams tank. This gas turbine is unique since almost all the heavy armor systems in the world use diesel propulsion systems. Lycoming operates the Stratford Army Engine Plant (SAEP) which produces an annual average of 540 engines for the Abrams tank. Lycoming has committed considerable resources to research, development, engineering, and prototyping of the gas turbine. "Much of this research and development activity may be explained by the fact that there exists a fierce competition between gas turbine and diesel engine proponents in the future propulsion units for heavy armor."[44]

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[44]Ivars Gutmanis, *Research and Development, Engineering and Production of Abrams Tank and Bradley Fighting Vehicle System Under Reduced Funding for the U.S. Industrial Base*, Report prepared for the U.S. Congress, Office of Technology Assessment, International Security and Commerce, Washington, D.C.: Sterling Hobe

This competition requires SAEP to maintain technologically advanced manufacturing equipment and processes in order to produce engines.

f. Armament, Munitions, and Chemical Command

The Armament, Munitions, and Chemical Command (AMCCOM) oversees Government furnished material suppliers such as Hughes Aircraft, Computing Devices of Canada, Rock Island and Watervliet Arsenal, Kollmorgan, Plessey, and Kearfott Guidance Navigation, who provide components to GDLS.

g. Department of Energy Depleted Uranium Facility

The Department of Energy (DOE) Depleted Uranium (DU) facility in Idaho Falls, Idaho, is the only facility in the U.S. currently capable of producing DU armor for the Abrams tank and penetrators for the 120mm sabot round used with the tank's cannon. Should U.S. tank production terminate, the plant will close because tanks produced for Foreign Military Sales (FMS) will not be equipped with DU armor but with conventional armor. The last new U.S. tank requiring DU armor is currently scheduled for completion in March 1993. The FY93 DOD appropriation will extend DU production until 1995.

4. Evaluation Factors

The following cost factors were used to evaluate the three options presented in order to standardize the analysis. The cost factors were human resources, facility

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Foundation, October 1991, p. 111.

layaway, equipment layaway, equipment removal, environmental, close out penalty, maintenance/caretaker, program management, and miscellaneous costs.

a. Human Resources Costs

Human resources costs were discussed previously and include those costs associated with contractor personnel such as separation pay, health care, supplemental benefits, group insurance, pension plans and dental care. The Government is contractually liable for such human resource separation costs.

b. Facility Layaway Costs

Facility layaway costs are costs associated with real property or physical plant layaway. Facilities can be classified as property (other than material, special tooling, military property, and special test equipment) for production, maintenance, research, development or test. Facilities also include real property, buildings, structural improvements, and plant equipment.

c. Equipment Layaway Costs

Equipment layaway costs are costs associated with laying away industrial plant equipment, other plant equipment, special test equipment, and special tooling.[45] Definitions for the different categories of equipment are contained in Appendix B. Equipment details are also specified in the Federal Acquisition Regulation (FAR) Part

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[45]Defense Systems Management College, *Integrating Industrial Preparedness Into The Acquisition Process, A Guide for Program Managers*, First Edition, Fort Belvoir, VA: DSMC, April 1989, p. 5.1-1.

45, *Government Property* and DOD Directive 4275.5, *Acquisition and Management of Industrial Resources*.

d. Equipment Removal Costs

Equipment removal costs are costs for planning, disconnecting, packaging, crating, handling and shipping of Government-owned equipment.

e. Environmental Costs

Environmental costs include site surveys, publication and update of an environmental cleanup plan, and other remedial actions in accordance with Environmental Protection Agency (EPA) regulations.

f. Close Out Penalty Costs

The close out penalty is a contractual obligation incurred by the Government for reduction of the production rate. General Dynamics executes termination costs in accordance with the requirements identified in its contracts. These requirements identified by Federal Acquisition Regulation (FAR) 52.249-2 *Termination for Convenience of the Government* and FAR 52.249.9 *Default* are the guiding documents as to how GDLS determines and calculates termination costs.

g. Maintenance/Caretaker Costs

Maintenance/caretaker costs are the costs associated with utilities, maintenance, security, fire protection, and staff of the laidaway facility and its equipment.

h. Program Management Costs

Program management costs or PM Office costs are those efforts required to coordinate internal and external office functions, and track costs, including costs for inventory, progress and preparation of reports to maintain schedules and budgets.

i. Miscellaneous Costs

Miscellaneous costs are those costs that deal with layaway which are not covered in the work breakdown structure.

Given these cost factors, analysis of the effects of each option on the tank industrial base and more importantly, budget considerations, is standardized.

C. COST ANALYSIS

An analysis of the potential cost effects of each of the three options available to DOD, Congress and industry is presented below.

1. OPTION ONE: The Army should mothball the Lima, Ohio tank plant after the last Abrams tank is built.

This option is analyzed through the costs projected to terminate production from a current production rate of thirty tanks per month. Layaway is defined as the process of retaining and storing industrial facilities that are no longer required to support current production but may be required to support production at a later date. Because new production of the Block III tank was originally projected to begin in fourth quarter, FY01, cost planning figı ɜ were based on the assumption that there would be an eight- to ten-year closure from March 1993 to late 2001. At 2001, production would begin on the Block III tank. Costs for the total layaway at each facility are contained in Table VIII.

TABLE VIII
TOTAL LAYAWAY IN PLACE (IN MILLIONS OF DOLLARS)

	DATP	LATP	GDLS	ATD	SAEP	AMCCOM	DOE	TOTAL
Human Resources	26.9	37.4	23.0	3.2	0.0	0.0	5.8	96.3
Facility Layaway	6.1	11.2	8.8	1.0	0.0	3.7	0.0	30.8
Equipment Layaway	5.4	22.1	7.9	1.4	1.8	1.2	0.0	39.8
Equipment Removal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EPA Bill	8.4	11.6	1.2	0.3	Unk	0.0	28.7	50.2
Close Out Penalty	14.6	0.0	0.0	0.0	0.0	0.0	0.0	14.6
Maint. & Caretaker	37.8	61.6	34.5	58.3	4.2	1.2	118.5	316.1
PM Office	5.5	8.4	6.5	0.8	0.0	0.2	0.0	21.4
Miscell.	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
Total	104.7	152.3	81.9	65.0	6.0	6.3	153.2	569.4

Source: *Abrams Program Closure Study (Austere)*, 13 August 1991.

As reflected in Table VIII, total closure cost was estimated to be $569.4 million. The bulk of the cost comes from the primary tank production facilities at LATP and DATP, and the DOE DU facility closure.

a. Advantages

The advantages from a cost perspective are that DOD will at least maintain the capability to restart production in the event of new production or a major mobilization. However, production restart from total layaway is estimated to be seventytwo months. There are benefits to putting tank production in a mothballed status given the excess number of tanks in the U.S. Army's inventory. The startup costs for the Block III tank or FMBT are reduced compared to starting up from a completely dismantled tank production capability. Laying away the tank production facilities also allows caretaker personnel to initiate remedial EPA actions and/or remain current with changing EPA regulations. Additionally, termination of production allows DOD to redirect funds to other programs in the acquisition cycle in this era of reduced spending.

b. Disadvantages

The cost of shutting down the tank industrial base is high and revised cost estimates could be higher. For example, the September 1991 cost for total layaway was $569.4 million. In a later study conducted by an independent industrial analysis team released on April 1992, costs for total layaway were increased by $100 million over the previous estimate to $670 million.

> There is currently $968 million projected as non-productive costs to lay away the tank industrial base for ten to fifteen years. This includes $20 million a year in non-productive costs to decommission the DU armor facility. Restart costs for layaway for FMBT is $1.4 billion, $620 million of that is for work on Abrams tooling, much of this cost could be avoided by maintaining a warm base.[46]

Total DU facility closure cost is estimated at $153.2 million with restart costs after a two-year or more closure projected to be $175 million due to the added costs of retraining and recertifying personnel. Additionally, many of the EPA, OSHA

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[46]MG(Ret) Oscar Decker, Joseph Aquino and Stephen D. Napier, *Military Industrial Base Sector Study, Tracked and Wheeled Vehicles*, Final Report from the Independent Industrial Analysis Team to Headquarters, U.S. Army Material Command, 28 April 1992, p. 10.

and Nuclear Regulatory Commission (NRC) licenses will have expired at the two-year mark adding to the restart costs after the two-year mark.

Table IX depicts the costs estimated for restarting production from total plant closure given that the DU facility has been closed for two or more years. The Abrams column shows the varying rates and costs associated with restarting Abrams production while the Armored Systems Modernization (ASM) column depicts the varying rates and costs of restarting production with a future main battle tank or the Block III. The higher costs in the ASM column are attributed to retooling and facilities upgrade required to begin production on a new weapon system.

TABLE IX
RESTART/RAMP-UP COSTS

	FY92 Costs in Millions	
	Abrams	**ASM**
0 Vehicles/month	740	1,400
10 Vehicles/month	300	1,000
15 Vehicles/month	240	950
20 Vehicles/month	215	935
30 Vehicles/month	170	820

Source: TACOM.

Since this chart assumes an eight- to ten-year closure period, costs will increase considerably if the facilities remain closed beyond this length of time or the overall economic situation deteriorates.

c. Conclusions for Option One

This course of action becomes costlier over time. Although the data presented are estimates, rapidly changing decisions and policies being made by DOD, Congress, and industry could easily affect the estimates. The data serve to show that the costs involved in shutting down a single source for tank production will outweigh the long-term benefits of such an action. For example, shutting down tank production at a cost of $569.4 million would require $764 million to restart production at a later date for a total cost of $1.3 billion with no tanks to show for these costs. In comparison, GDLS has proposed to upgrade 240 older M-1 tanks per year to the M1A2 at a cost of $619 million.[47] The costs to shut down then would not seem worthwhile in comparison to keeping some production active. It would take fifty-one months to produce the first Abrams from total layaway at a cost of $1.1 billion and $1.4 billion for the Block III tank. With the funding for closure spread out over several years, the annual budget process would not guarantee the requested funds from year to year. The risk is that less than requested funding will force DOD and industry to execute a less than adequate closure process, potentially leading to further degradation of U.S. tank production capability and increased future restart costs.

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[47]Gary R. Diaz and Donald L. Gilleland, "The M1A2 Conversion Programme," *Military Technology*, February 1992, p. 6.

2. **OPTION TWO: The Army should reduce production to the minimum production rate that will keep the factory operational until the factory retools for the next generation tank.**

This option assumes a production rate of twenty tanks per month which will maintain the tank industrial base in its entirety. This warm base would leave DATP closed for production but remain open for complex machining operations and some component production until Abrams procurement is complete. Table X depicts the costs required to reduce production to twenty tanks per month.

TABLE X
LAYAWAY TO 20 TANKS PER MONTH
(IN MILLIONS OF DOLLARS)

	DATP	LATP	GDLS	ATD	SAEP	AMCCOM	DOE	TOTAL
Human Resources	15.3	4.0	1.9	3.2	0.0	0.0	0.0	24.4
Facility Layaway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Equipment Layaway	1.5	3.0	0.3	0.0	0.1	0.0	0.0	4.9
Equipment Removal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EPA Bill	1.5	0.0	0.0	0.0	Unk	0.0	0.0	1.5
Close Out Penalty	14.6	0.0	0.0	0.0	0.0	0.0	0.0	14.6
Maint. & Caretaker	36.9	0.0	0.0	0.0	0.0	0.0	0.0	36.9
PM Office	0.8	0.2	0.2	0.0	0.0	0.0	0.0	1.2
Miscell.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	70.6	7.2	2.4	3.2	0.1	0.0	0.0	83.5

Source: *Abrams Program Closure Study (Austere)*, 13 August 1991.

Total cost for this option is $83.5 million. The majority of costs would come from production termination at DATP. As shown in Table X, the bulk of DATP's costs comes from workforce layoffs, maintenance/caretaker costs, and close out penalty costs.

a. Advantages

The biggest advantage of this option is that production of Abrams will continue. The biggest cost savings comes from not closing the DU facility because closure costs at the DU facility alone are $153.2 million. Detroit Army Tank Plant will retain complex machining and component production for the near-term. For this reason, the majority of costs for this option come out of DATP to maintain the laidaway tank production capability. Overall the tank industrial base essentially remains intact and causes future ASM and future main battle tank startup costs to be significantly reduced as compared to total layaway.

b. Disadvantages

Production at a low production rate would result in allocation of indirect costs to fewer tanks. Examples of these overhead costs would be things such as depreciation of plant equipments and tooling, insurance, rent, security and utilities. There would also be a loss of quantity discounts on parts purchases and components that are attributable to higher production rates. An example of per unit cost differences can be shown in the various production mixes for FY94. In FY94, should GDLS produce a total of 10 M1A1 tanks and no M1A2 tanks, the unit cost of the M1A1 will be $6.6 million. Should GDLS produce 10 M1A1 tanks and 20 M1A2 tanks, unit costs for the

M1A1 would drop to $3.9 million each.[48] The allocation of overhead to fewer tanks would result in higher per unit costs extending down to the subcontractor and resulting in fewer purchases of tanks for the dollar.

c. *Conclusions for Option Two*

This option combines cost avoidance with preservation of the tank industrial base and the DOE DU facility. This combination occurs because the cost to reduce production from thirty to twenty tanks is minimal given the benefits of preserving the tank production base. For example, reducing production at a cost of $83.5 million is far less than terminating tank production and restarting at a future date at a cost of over $1 billion (Option One). It is assumed that future ASM or FMBT startup costs will also be reduced since production would continue.

3. OPTION THREE: The Army should complete production of the M1A1 tank and then use the factory to retrofit/upgrade older model tanks to the M1A2.

This conversion program bridges the M1 to the Block III tank or FMBT by incorporating emerging technologies into the Block II tank. The retrofit program consists of taking an M1 or M1A1 tank and converting it to an M1A2 in a process described in Chapter Two. The conversion costs are less for an M1A1 to M1A2 than for an early model M1A1 and M1IP to M1A2 because the early model tanks were equipped with the 105mm gun and fire control system instead of the 120mm gun found on the M1A1 and

[48]U.S. Army Tank-Automotive Command, *Abrams Program Closure Study*, Warren, MI: Unpublished Slides, September 1990, Slide VC 17.

M1A2. Overall, the cost to convert an older Abrams to an M1A2 is roughly two-thirds the cost of building a brand new M1A2 tank.[49] The costs to convert current M1A1 tank production to M1A2 conversion capability are contained in Table XI.

TABLE XI
LAYAWAY TO 20 M1A2 TANK CONVERSIONS PER MONTH
(IN MILLIONS OF DOLLARS)

	DATP	LATP	GDLS	ATD	SAEP	AMCCOM	DOE	TOTAL
Human Resources	16.2	4.0	1.9	3.2	0.0	0.0	0.0	25.3
Facility Layaway	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0
Equipment Layaway	2.2	4.2	0.3	1.4	1.8	0.0	0.0	9.9
Equipment Removal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EPA Bill	1.5	0.0	0.0	0.3	Unk	0.0	0.0	1.8
Close Out Penalty	14.6	0.0	0.0	0.0	0.0	0.0	0.0	14.6
Maint. & Caretaker	36.9	0.0	0.0	58.3	4.2	0.0	0.0	99.4
PM Office	0.9	0.2	0.2	0.8	0.0	0.0	0.0	2.1
Miscell.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	72.3	8.4	2.4	65.0	6.0	0.0	0.0	154.1

Source: *Abrams Program Closure Study (Austere)*, 13 August 1991.

The cost of this option is $154.1 million, with the majority of costs coming from production termination at DATP and partial closures at Allison Transmission Division (ATD) since refurbished transmissions would come from existing tanks. Costs to partially layaway SAEP and ATD total $71.0 million. Some of the other costs are

[49]Gary R. Diaz and Donald L. Gilleland, "The M1A2 Conversion Programme," *Military Technology*, February 1992, p. 1.

attributed to retooling for the M1A1 to M1A2 upgrade at LATP. Hull refurbishment, as stated earlier, would most likely take place at depot organizations.

a. Advantages

The advantages of this option are that a conversion rate of twenty tanks per month will maintain the DOE capability to produce DU and the production rate will also reduce future ASM or FMBT startup costs.

b. Disadvantages

The disadvantages of Option Three are that the entire tank industrial base is not utilized because ATD and SAEP are now utilized for spares and repair parts support leading to partial layaway of these two facilities. This adds to maintenance/caretaker costs at both facilities which comprise 64.5 percent of the $154.1 million overall costs to initiate the reconversion program. Since this $154.1 million cost is projected across FY92 to FY01, limited funding or funding shortfalls during this nine-year bridge to FY01 could hinder the reconversion process, force production to drop below twenty tanks per month, and add to per unit costs of the system.

c. Conclusions for Option Three

Although Option Three costs $154.1 million to execute, it will provide the Army with the most modern tank in the world. This plan is a compromise between total plant closure and continued production of the M1A1. Although it does not preserve the entire tank industrial base, it will do the following: (1) maintain most of the key manufacturing capabiliti -, (2) field a superior system based on existing systems and reusable components combined with emerging technologies, and (3) bridge the gap between the Abrams tank and the tank of the future.

D. SUMMARY

From a cost perspective the option that best minimizes cost to the Government is Option Two because it will only cost $83.5 million and continue tank production. The next best option is Option Three because the reconversion option will cost $154.1 million and will also continue tank production. Finally, the most expensive and detrimental to the industrial base is Option One, which is total layaway of the industrial base at a cost of $569.4 million. Not only is it the most costly, but the restart costs from total layaway would be in excess of $1.0 billion for the ASM or Abrams program.

V. THE SUBCONTRACTOR BASE

A. INTRODUCTION

The purpose of this chapter is to analyze the options available to second-tier subcontractors for maintaining the tank industrial base. The tank industrial base can be divided into five sectors or industrial segments and will be analyzed as such. The five segments previously discussed in Chapter II are: (1) electronics/optics, (2) complex machining, (3) basic materials, (4) weapons, and (5) propulsion.[50] Each of the five industrial segments is further broken up into entities that supply General Dynamics-Land Systems Division (GDLS) or include firms that sell tank components to the Department of Defense (DOD), which in turn supplies the components to GDLS as Government Furnished Equipment (GFE).

B. OVERVIEW

As described in Chapter II, tank production is a task that requires complex component assembly techniques incorporating advanced technologies in the production process. "Historically in the U.S., the prime contractors of heavy armor have relied for a significant portion of these components to be supplied by a number of first-tier or

[50]The information presented in this chapter was drawn from two sources. The first source was an independent study completed by the Sterling Hobe Foundation in 1991 for the U.S. Congress, Office of Technology, International Security and Commerce. The second source was from a 28 April 1992 Tank-Automotive Command Study covering the propulsion and basic materials industrial segments of the tank industrial base.

principal subcontractors."[51] In the Abrams tank case, these firms supply to Abrams' prime contractor, GDLS. Required components are then assembled by GDLS into the M1A1 or M1A2 tanks.

The subcontractors analyzed in this chapter represent a portion of the 18,000 firms that provide components that go into producing a tank.[52] These firms range from those totally dependent on tank production to multiproduct firms that manufacture components and end items for DOD and commercial markets. In some cases, tank components and technologies have dual uses in both the military and commercial sectors. Often, the proportion of these subcontractor assets devoted to tank production represents a small portion of the firm's total assets. This in turn, may suggest that the financial condition, technology status, and personnel training of these subcontractors are determined by sales in the commercial sector rather than by tank component contracts.[53] In other cases, subcontractors such as Textron Lycoming, the engine manufacturer for the tank, are almost totally dependent on tank production. To standardize policies governing every tank industrial base subcontractor would then be unrealistic.

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[51]Ivars Gutmanis, *Research and Development, Engineering and Production of Abrams Tank and Bradley Fighting Vehicle System Under Reduced Funding for the U.S. Industrial Base*, Report prepared for the U.S. Congress, Office of Technology Assessment, International Security and Commerce, Washington, D.C.: Sterling Hobe Foundation, October 1991, p. 45.

[52]U.S. Congress, Congressional Budget Office, "Alternatives For The U.S. Tank Industrial Base," A CBO Study, February 1993, p. 10.

[53]Gutmanis, p. 49.

The following analysis suggests that tank subcontractors will fall into two categories: those which maintain industrial capability and those which reduce it.

TABLE XII
CHARACTERISTICS GOVERNING SUBCONTRACTORS' FUTURE INDUSTRIAL CAPABILITIES FOR ABRAMS COMPONENT PRODUCTION

Characteristics that Maintain Industrial Capability	Characteristics that Reduce Industrial Capability
Market Characteristics	
Markets for Abrams components exist in other DOD programs and commercial sector	Markets for Abrams components consist exclusively of the Abrams Program
Technology Characteristics	
Abrams components are manufactured on production lines and/or by use of technologies that can be used in other product manufacture	Abrams components are manufactured on production lines and/or by use of technologies that cannot be used in other product manufacture
Tank component production lines and/or technologies can be modified for manufacturing other products	Tank component production lines and/or technologies cannot be modified for manufacturing other products
Types of Firm Characteristics	
Subcontractor represents a division of a multiproduct industrial entity	Subcontractor is the sole industrial entity

Source: Gutmanis.

The subcontractor base forms a continuum with regard to their ability to remain viable suppliers to the Abrams tank program after funding is reduced or cut. At one end of this continuum,

> ...are subcontractors that will be able to supply the required components for the Abrams tank in the future, even in the event the funds for the Abrams tank are completely cut. At the other end there are firms that will close down their Abrams tank operations if the Abrams tank funds are significantly reduced.[54]

[54]Gutmanis, p. 82.

The diversity of subcontractors should suggest that the policy options to maintaining the tank industrial base have to be tailored to the various subcontractors' needs and that the future composition of a tank industrial base among subcontractors will depend on the future funding levels for the Abrams tank program and the specific policies undertaken by DOD.

C. SUBCONTRACTOR ANALYSIS

The analysis that follows examines key second-tier subcontractors in each of the following industrial base segments: (1) electronics and optics, (2) complex machining, (3) basic materials, (4) weapons, and (5) propulsion. Each firm provides key items or services that make up the Abrams tank. A list of key subcontractors, parts manufactured, and number of facilities utilized is contained in Table XIII.

1. Electronics and Optics

There are twelve major subcontractors that produce or are major suppliers of electronics and optics for the Abrams tank. Examples of electronics and optics are the fire control system, thermal imaging system, and turret electronics.

Recent trade studies indicate that there are about 200 optics firms in the U.S. Of these 200 firms, there are about 30-40 that engage in over 80 percent of their production for DOD. On the electronics side, there are about 100 electronics firms in the U.S., with the majority of them providing varying levels of products or services to DOD. Overall, these products represent advanced technology and have high costs. For example, the Thermal Imaging System (TIS) on the Abrams costs over $100,000 per unit. These high unit costs make the products expensive for sale in the commercial sector and so the market is limited, even though many law enforcement agencies would like to possess thermal imaging equipment.

TABLE XIII
SUBCONTRACTOR COMPOSITION FOR THE ABRAMS TANK

Principal Tank Components	Component	Facilities
Electronics & Optics		
Cadillac Gage	Stabilization System and Turret Drive	2
Computing Devices of Canada	Ballistic Computer and Flat Panel Display	1
Electro Tech	Slip Ring	1
General Electric	Radio Interface Unit	1
Hughes Aircraft	Thermal Imaging System and Laser Rangefinder	1
J-Tech Associates	Crosswind Sensor	1
Singer Kearfott	Line of Sight Data Link	1
Kollmorgan Corporation	Gunner's Auxiliary Sight and Commander's Weapons Station	1
Precision Sensors	Pressure Sensors	1
Smiths Industries	Position/navigation Unit	1
Texas Instruments	Hull/Turret Electronics Unit and CITV	1
Vista Controls	Turret Electronics	1
Complex Machining		
GDLS Scranton/DATP/LATP		3
Basic Materials		
Lukens Steel Corporation	Armor Steel Plate	1
Atchison Casting Corporation	Cast Steel	1
U.S. DOE DU Facility	Depleted Uranium	1
Weapons		
Rock Island Arsenal	Main Gun Mounts	1
Watervliet Arsenal	120mm Cannon	1
Propulsion		
Textron Lycoming-SAEP (GOCO)	Turbine Engine	1
Allison Transmissions	Transmission	1
LOC Performance	Final Drives	1
Gibraltar Sprocket Company	Sprockets	1
Urdan Industries Limited	Roadwheels	1
Goodyear Tire and Rubber	Track	1
Donaldson and United Air Filters	Air Filters	2
Bendix Corporation	Starter	2
Vickers Corporation	Hydraulic Pump	1

Source: GDLS.

Many of these firms export some of their products to foreign nations for use in foreign weapon systems. "In the face of significant cuts in all defense programs, these firms may have significant difficulties in finding markets for their products."[55] It is estimated that as tank program dollars shrink, more firms will terminate business relationships with DOD. New firms for these products will require at least one to two years for personnel training, equipment installation, testing, etc., before an adequate supply of these advanced products can be obtained from new suppliers. If new suppliers do not have the opportunity to advance along the learning curve via significant production experience (as may be the case in the event demand for such products is reduced), the feasibility of obtaining electro-optical products may be hindered.[56]

a. Cadillac Gage

Cadillac Gage is a subsidiary of Textron Incorporated and manufactures the stabilization system and turret drive for the Abrams tank. It has two dedicated facilities for Abrams component production and employs 500 personnel. Cadillac Gage also manufactures the stabilization system for Foreign Military Sales (FMS) vehicles which make up about half of its business. About 500 units are produced annually each worth $70,000. Should tank production cease or taper off significantly, the management of Cadillac Gage has "proposed to either shut down the two facilities or convert these for other products in the event the demand for the Abrams tank stabilizer is reduced to below

[55]Gutmanis, p. 54.

[56]Gutmanis, p. 54.

200 per year from the present volume."[57] Two hundred units is the minimum economically feasible alternative under any option above foreign military sales for Cadillac Gage to remain in business with the Abrams tank program.

b. Computing Devices of Canada

Computing Devices of Canada (CDC) manufactures the ballistic computer and the flat panel display for the Abrams tank and is a division of Control Data Canada Limited. It is a microelectronics product manufacturer specializing in computers. It is also engaged in FMS with components provided to the British Challenger tank, other foreign fixed and rotary wing aircraft, and shipboard displays. The management of CDC plans to keep production lines for the Abrams open even if funding for Abrams is totally cut, because the same production lines are used in other microelectronic product manufacture. However, the absence of manufacturing activities for the Abrams components "in excess of three years will result in significant atrophy in terms of the Abrams tank product and process technology."[58]

c. Hughes Aircraft

Hughes Aircraft Ground Combat Systems produces the Thermal Imaging System (TIS) and Laser Rangefinder (LRF) for the Abrams tank. These electro-optical products are two of five that Hughes produces for DOD. The TIS is a sight that allows the gunner and tank commander to acquire and engage targets in periods of limited

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[57]Gutmanis, p. 88.

[58]Gutmanis, p. 90.

visibility by using the thermal signatures of animate and inanimate objects. The LRF allows the gunner and tank commander to fire a laser beam to a target which returns a range in meters that becomes part of the ballistic solution in the firing sequence. The TIS represents cutting edge technology and is a fairly complex system. The complexity of the TIS required the use of advanced products and process technologies, requiring at least ten years to execute the research and development associated with the system. Only Hughes' utilization of concurrent engineering in the manufacturing process and well-established research and development base shortened the original research and development effort. In addition t the long lead times, highly skilled personnel must have experience in actual product manufacture and training, followed by qualification on the production line. This process takes a minimum of eighteen months.

Hughes relies on over 100 third- and fourth-tier subcontractors for components for the TIS and LRF with some of these firms being one-of-a-kind manufacturing entities. Should funding for the Abrams reduce demand to 120 tanks per year or less or ten tanks per month, Hughes plans to shut down the assembly line and manufacture other products. If this happens, alternatives to Hughes are Honeywell, Loral, Texas Instruments and Martin Marietta. But as was stated earlier, new firms for these products will require at least one to two years for personnel training, equipment installation, testing, etc., before an adequate supply of these advanced products can be obtained from new suppliers. If new suppliers do not have the opportunity to advance along the learning curve via significant production experience, the feasibility of obtaining electro-optical products may be hindered, especially if there is a sudden increase in product demand given emergency conditions.

d. J-Tech Associates

J-Tech Associates manufactures the crosswind sensor for the tank. The crosswind sensor measures wind speed and direction, which is one variable used in computing the ballistic solution in the tank's ballistic computer. The crosswind sensor was adopted from a commercial gas flow measuring instrument that J-Tech also manufactures. The firm currently employs 65 personnel. About 50 percent of J-Tech business is dedicated to Abrams crosswind sensor production. J-Tech purchases most of the components of the sensor, which are primarily microelectronic components, from third- and fourth-tier subcontractors. In the event J-Tech chooses to exit crosswind sensor production, it is estimated that about 200 other firms would have the capability to manufacture crosswind sensors.

e. Singer Kearfott

Singer Kearfott manufactures the Line-of-Sight (LOS) system for the Abrams tank and 80 percent of its business is with DOD. The LOS links the physical aspects of the main gun with the electro-optical functions of the fire control system on the tank. Kearfott led the development of the LOS and continues to perfect and incorporate LOS technology through its continuing research and development efforts. Kearfott relies on over 50 third- and fourth-tier subcontractors and purchases all the components used to manufacture the LOS from these vendors. Again, some of these vendors are unique product firms producing one-of-a-kind components.

Kearfott has indicated that it will continue to manufacture electro-optical systems whether funding continues for the Abrams or not. If the demand for LOS production drops below 324 units per year as compared to the current production of 840 units per year, and DOD is not willing to negotiate on higher per unit costs, then Kearfott will close down the Abrams LOS production line.

f. Smiths Industries

Smiths Industries manufactures the position/navigational unit for the M1A2 tank. The positional/navigational unit operates similar to the Global Positioning System (GPS), except that the positional/navigational unit is integrated into various command and control systems in the tank. The unit itself consists of several gyroscopes combined with microelectronic components. The unit only represents 10 percent of Smiths Industries annual sales and represents 90 percent of the firm's land navigation product line. Smiths Industries purchases all of its components from third- and fourth-tier subcontractors such as Motorola, Intel, etc. The firm employs 1650 personnel at one facility and annual production is 380 units. The process technology for the unit is relatively stable but the manufacturing processes are very labor intensive.[59] Because of the labor intensive production process,

> ...the principal requirement for the maintenance of the industrial base for positional/navigational units is a high level of production. High level production

[59]Gutmanis, p. 95.

is required because the manufacture of the gyroscopes is highly sensitive to economies of scale.[60]

The minimal acceptable production rate for Smiths Industries is 240 units per year compared to the current 380 units. If the minimal rate is decreased. Smiths Industries plans to exit this product line, although other firms such as Kearfott, Litton Systems and Honeywell have the capability to manufacture this unit if necessary. But again, new firms for these products will require at least one to two years for personnel training, equipment installation, testing, etc., before an adequate supply of these advanced products can be obtained from new suppliers. If new suppliers do not have the opportunity to advance along the learning curve via significant production experience, the feasibility of obtaining electro-optical products may be hampered.

g. Texas Instruments

Texas Instruments (TI) manufactures the Hull/Turret Electronics Unit (H/TEU) for the Abrams tank. It also manufactures the Commander's Independent Thermal Viewer (CITV) for the M1A2 tank. About 75-100 personnel assemble the H/TEU with a larger number expected to assemble the CITV. A significant portion of the TI personnel engaged in Abrams component production and testing are highly experienced engineers and technicians.

In the event that funding for the Abrams is reduced or terminated, most of these employees will likely be absorbed into other TI operations. It is also likely that the H/TEU and CITV produced at some future restart date will incorporate most of the

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[60]Gutmanis, p. 95.

technological advances made to date because the microelectronic components "result from broad, industry-wide, technological improvements as well as from the research and development undertaken explicitly for the Abrams tank component."[61] So in the event production resumes, TI will be able to reinstate production of the H/TEU and CITV with a slight delay. In sum, specific policies to preserve the industrial base for these components is not necessary. The only requirement will be to keep a proper spare components inventory.

h. Vista Controls

Vista Controls manufactures special purpose prototype computers for DOD land systems. It makes the stabilization computer for the Abrams which stabilizes the firing mechanism during gunnery. The cost for this unit is $12,000. Vista Controls employs 30 people with the majority of them dedicated to making the computer. All components for the computer are purchased from vendors with Vista Controls performing assembly and software integration. The management of Vista Controls is depending on the continuous production of the Abrams through the proposed retrofit program to the M1A2 in order to continue its product line. Should the program be cancelled, Vista Controls will revert to prototype assemblies for DOD and enter the commercial market.

2. Complex Machining

General Dynamics-Land Systems Division operates all three complex machining facilities for the Abrams. As described in previous chapters, the operations

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[61]Gutmanis, p. 87.

take place at the Lima Army Tank Plant (LATP), Scranton Complex Machining Plant, and Detroit Army Tank Plant (DATP). Machining operations involve manufacture of components such as roadwheel arms and rotary shock absorbers for the tank. DATP was closed in October 1991 but 50 percent of gun mount production and assembly is still being undertaken at DATP according to GDLS. This leaves LATP and the Scranton, Pennsylvania Complex Machining Plant as the two key machining facilities in operation. Conversion of any of these facilities to other operations in the event of closure is not economically feasible nor are there any other facilities in the U.S. capable of undertaking the complex machining tasks carried out by GDLS.

3. Basic Materials

Abrams tank production requires basic material inputs from three industry segments. The industry segments are: (1) armored steel plate production, (2) large-scale steel casting production, and (3) depleted uranium production.

a. Lukens Steel Corporation

Lukens Steel Corporation is the sole current producer of steel plate for the Abrams program. Because of the relatively assured future supply of steel plate for heavy armor, steel plate production can be started at any time but at significant cost in the event of a future restart from production termination. The current industrial base for armor plate is adequate to accommodate the downsizing tank industrial base and should Lukens Steel exit the armor plate business, alternate producers for steel plate are Bethlehem Steel, U.S. Steel, and Oregon Steel.

b. Atchison Casting Corporation

Established in Atchison, Kansas in 1872, the Atchison Casting Corporation is one of the largest steel foundries in the U.S. It has supplied GDLS since 1978 with sixteen separate steel castings such as turret rings for the Abrams. Steel casting consists of casting followed by rough machining. Atchison Casting specializes in large castings for locomotives and heavy construction equipment and can cast steel up to 50,000 pounds in weight. Of its 600 employees, 50 percent are involved in Abrams related production. A significant portion of the personnel employed by the firm are highly skilled technicians, welders, melters, and process engineers. Due to these developed skills, on-the-job training for large steel casting only exists at the Atchison foundry.

Atchison Casting has continually upgraded its manufacturing production capabilities with advanced equipment such as computer-assisted machinery for rough machining and other technological advances. The annual minimum volume of production is 240 units. At lower volumes, it will seek other markets for its products such as steam turbines and will reconfigure the Abrams production line for other products. Possible alternatives to Atchison are FMC and the Birdsboro Foundry, although "Atchison Casting has unique technical capabilities that will be difficult to duplicate."[62] The Birdsboro Foundry is a relative newcomer to steel casting and lacks the technical experience in steel casting compared to Atchison.

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[62]Gutmanis, p. 56.

c. *U.S. Department of Energy Depleted Uranium Facility*

The U.S. Department of Energy (DOE) Depleted Uranium (DU) facility was discussed in previous chapters. Closure costs as of December 1992 are $20 million. If current DU armor package lines are terminated, restart from total layaway would take approximately 42 months and cost $168 million. Although a one-of-a-kind facility, an alternative to the DU facility is the Nuclear Metals Industries, in Concord, Massachusetts.

> By nature of design and usage, the armor package does not lend itself to mass production on a commercial basis. Accordingly, to facilitize a commercial base, considerable investment by the Government would be required.[63]

The Department of Defense can expect to pay a very high price to enable this alternate subcontractor to produce DU armor for the Abrams tank. Combined with closure costs and long lead times for future restart at the DOE facility, it is not economically feasible to shut down the DOE DU facility.

4. Weapons

The only facility producing the 120mm cannon for the Abrams tank is Watervliet Arsenal in New York. Watervliet is also the only facility capable of producing large caliber gun tubes for all artillery and armor systems in the U.S. Rock Island Arsenal produces the gun mount, breech mechanism, etc., for the main gun and again is a unique facility. Rock Island produces 50 percent of the gun mounts for the

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[63]U.S. Army Tank-Automotive Command, *1992 Industrial Sector Study: Tracked and Wheeled Vehicles*, Warren, MI: Production Management Division of the Acquisition Center (AMSTA-IC), 28 April 1992, p. 45.

Abrams program while the remaining gun mounts are produced at DATP.[64] Both TACOM closure studies identified 129 personnel at Watervliet Arsenal and 410 personnel at Rock Island Arsenal who would be affected given funding cutbacks in the Abrams program. Both of these facilities are Government-owned and operated and closure of these facilities is not expected. A reduction of operations may take place resulting in a loss of skills and experience that have been the cornerstone of these facilities since the early 1800's.

5. Propulsion

There are ten industrial entities that manufacture the components of the Abrams tank propulsion system. As seen thus far in the previous four industrial segments making up the tank industrial base, the firms providing the propulsion components range from those with very large civilian sector markets who will not be affected by changes in the Abrams tank program and those who are totally dependent on tank contracts for survival in the marketplace.

a. Textron Lycoming

Textron Lycoming manufactures the AGT1500 gas turbine engine for the Abrams tank at the Stratford Army Engine Plant (SAEP) in Stratford, Connecticut. The plant is a Government-owned, contractor operated (GOCO) facility and is the only facility where the engines are made. Textron's current industrial sales consist of 65 percent defense products and 35 percent commercial products. Textron supplies the

[64]M.A. Puzzuoli, Memorandum/facsimile to the researcher from Manager, Quality Programs, General Dynamics-Land Systems Division, 08 January 1993, p. 2.

AGT1500 engine as Government Furnished Material (GFM) to DOD who provides it to GDLS.

Textron currently produces 540 engines per year or 45 per month and for mobilization purposes can ramp up production to 90 per month or 1080 engines per year. Production lead time for engines is 23 months, since Textron must rely on over 60 third- and fourth-tier subcontractors to provide parts and components for engine production.

The gas turbine used in the Abrams tank is unique in that most other heavy armor systems such as the British Challenger and German Leopard II utilize diesel engines for their power plants. Textron devoted considerable effort to the research and development, engineering, and prototyping the gas turbine for use in the tank. The uniqueness of the gas turbine versus the diesel engine also has forced Textron to stay ahead of its competitors through continuing research and development efforts. "Much of this research and development activity may be explained by the fact that there exists fierce competition between gas turbine and diesel engine proponents in the future propulsion units for the heavy armor."[65] Textron has also expended significant effort to equip its production lines with advanced manufacturing technology so as to keep per unit costs and overhead down.

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[65]Gutmanis, p. 111.

Even if cutbacks in Abrams production take place, Textron's "potential for exiting military business after 1994 is considered minimal."[66] There will still be a need for spare engines for the tanks currently in the fleet. In any event, Textron has considered downsizing and developing and/or marketing new products and technologies. Should Textron exit tank engine production, an alternative subcontractor is General Electric, which has had significant experience in gas turbine technology for civilian and military applications.

b. Allison Transmissions

As a subdivision of General Motors, Allison Transmission Division (ATD) manufactures the X1100 transmission for the Abrams tank. Allison dominates the world's transmission market with over 80 percent of the total share. Its defense business is only 25 percent of its total sales, with the remaining 75 percent dedicated to commercial products. Allison manufactures the transmission at its four million square foot plant in Indianapolis, Indiana which was built in 1979. This plant maintains one assembly line for each transmission type produced. Of the 5700 employees at the ATD plant, 800 are currently dedicated to X1100 production. Some of the technical skills required by these employees working in the manufacture of transmissions require several years on-the-job training adding to production lead times in the event of production restart from a reduced capacity. The production line has a capability of producing 120 transmissions per month and it is currently operating the line at 45 percent capacity.

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[66]TACOM, *1992 Industrial Sector Study*, p. 47.

Production lead time is 300 days for normal production and 570 days from total layaway. Allison purchases parts and components for the X1100 transmission from over 60 third- and fourth-tier subcontractors, several who represent one of a few manufacturing entities capable of supplying specific products for the transmission.

Allison must continually undertake research, development, and engineering for its transmission technology resulting in constant improvements to the Abrams transmission. This is also a direct result of attempts by foreign firms to increase their own market share of transmission business at ATD's expense with the competition coming from Germany, the United Kingdom, and Japan. This technological edge also gives the transmission the built in flexibility for use with diesel or turbine technology, as presented in Textron Lycoming's situation where fierce competition exists between gas turbine and diesel engine proponents.

In September 1992, the Treasury Department's Committee on Foreign Investment in the U.S. (CFIUS) cleared the way for a German corporation, Zahnradfabrik Friedrichshafen AG(ZF) to purchase ATD.[67] Although the sale should be finalized in 1993, this has now raised Congress' concerns over the investment in U.S. defense industries by foreign entities and raises potential national security implications of mergers and acquisitions with foreign companies. In this instance, since ATD manufactures almost all of the U.S. Army's transmissions, the sale may have a significant impact on the decisions being made to preserve the tank industrial base.

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[67]Michael Sperling, "U.S. Congressman Questions GM Sale," *Defense News*, 11-17 January 1993, p. 25.

Allison expects to remain in business regardless of what happens to the Abrams program and should production be reduced, DOD should expect higher unit production overhead costs. Additionally there will be a need for spares in the future so a minimum requirement for transmissions can be anticipated.

c. *LOC Performance*

LOC Performance manufactures the final drive for the Abrams tank. The final drive is the unit which converts power from the transmission through the overfitting hub and sprocket which directly drives the track. Each tank has two final drives. LOC Performance is a machine shop dedicated to final drive production for the Abrams tank, with 90 percent of its business dedicated to DOD contracts and the remaining 10 percent dedicated to commercial sales. Final drive output at LOC Performance is 1700 units per year or enough final drives for 850 tanks. Production lead time for final drives is 360 days. LOC Performance represents a "typical relatively small metalworking enterprise, engaged in the machining operations of various metal components for various large firms."[68] The design and engineering requirements for the final drive are provided by GDLS, so no research and development is conducted by LOC Performance. LOC Performance relies on no outside suppliers for parts and components for the final drive.

At least five active producers exist in the U.S. that could readily undertake final drive production in the event LOC exits this market. Again, new firms for final drives will require some time to train personnel, install equipment, testing, etc.,

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[68]Gutmanis, p. 110.

before an adequate supply of these advanced products can be obtained from new suppliers. If new suppliers do not have the opportunity to advance along the learning curve via significant production experience, the feasibility of obtaining final drives in an emergency may be hindered. Overall, there is no significant industrial base problem in final drive production.

d. Gibraltar Sprocket Company

The Gibraltar Sprocket Company manufactures the sprockets for the Abrams tank. The sprocket is mounted to the rear hub which is connected to the final drive. The power is then transferred from the engine through the transmission, final drives, hubs, sprockets and finally tracks. There are a total of four sprockets on a tank.

There are only two sprocket companies in the U.S. with the other sprocket company being the Wisconsin Ordnance Works. Gibraltar produces sprockets for the Abrams and other tracked vehicles in the Army's inventory and so its business mix is 95 percent DOD business with the remaining five percent in commercial sales. The production facility is currently operating at 80 percent capacity and production lead time for sprockets is 180 days to produce 960 sprockets per month.

It is unlikely that Gibraltar will exit sprocket business in the event of Abrams production termination, but if a major reduction in defense expenditures takes place, it is anticipated that the company will restructure its operations. Currently there is no foreseeable problem maintaining an adequate industrial base for sprockets.

Gibraltar is the supplier for all combat vehicles and there will be a demand for spares, "so they have no intention of closing their facility."[69]

e. *Urdan Industries*

Urdan Industries Limited, is an Israeli firm which manufactures the roadwheel for the Abrams tank along with roadwheels for most U.S. and foreign tracked vehicles. Its U.S. subsidiary, Suspension & Parts Industries, Limited, maintains a U.S. office which handles the contract and administrative work for U.S. contracts. In reality, Urdan buys unfinished aluminum roadwheel castings in the U.S., ships them to Israel where the rubber rims are applied and wheels refinished, and then ships them back to the U.S. Abrams roadwheels represent 40 percent of Urdan's production.

The roadwheels are a part of the suspension system used on tracked vehicles. They keep the track in alignment during its revolution; they are mounted on suspension arms which are connected to torsion bars. When the tracked vehicle is in motion, the roadwheel rides on the inner surface of the track shoe.

Urdan produces 3000 roadwheels per month or 36,000 per year. Since the Abrams utilizes 28 roadwheel in the suspension system, that would equate to enough roadwheels for 1,286 tanks. Of the annual production, between 20 percent and 40 percent is dedicated spares production. Urdan relies on nine active suppliers in the U.S. for roadwheel technology such as forging, machining, melting, stamping and heat treating. If the Abrams program is reduced by at least 60 percent, it is expected that

[69]TACOM, *1992 Industrial Sector Study*, p. 58.

three to five of these suppliers would exit defense business. The ramifications for Abrams then is that all production processes involving roadwheel production would become totally dependent on a foreign firm since Urdan maintains the capability to manufacture the roadwheel entirely in Israel.

f. Goodyear Tire and Rubber Company

Goodyear Tire and Rubber Company is the principal track manufacturer for most U.S. tracked vehicles. The track is the last component in the vehicle's drive system. Driven by the sprockets and guided by the roadwheels, it is the contact point to the ground and enables the vehicle to move. The track manufacturing process requires forging, casting, heat treating, machining and rubberizing. The Abrams track utilizes the T158 track with a total of 156 shoes. Goodyear maintains 60 percent of its business with DOD and the remaining 40 percent in commercial sales. Goodyear has the ability to produce 25,000 shoes per month and is currently operating the track assembly line at 75 percent capacity. It can reach 25,000 shoes per month given a production lead time of 180 days. Currently of the 550 employees in its track manufacturing facility, 183 are engaged in Abrams track production.

Goodyear performs final track production by rubberizing and assembling the metal track. Goodyear relies on FMC Corporation for the metal track components. Manufacture of the track by use of forging technology is a complex technology and the FMC facility is periodically upgraded with advanced forging equipment. FMC's production lead time for tooling and molds is 60 days. Most of the cost of track is attributed to the dies required to produce the track. Carbo Tools is FMC's diemaker and it too, requires at least 60 days production lead time to manufacture the dies for the T158 track.

Low level production for track is economically unfeasible to Goodyear since this level of production for tanks would equate to less than one month's production of track for Goodyear. Manufacturing spares for the Abrams is acceptable only if two conditions are met: (1) appropriate minimum production of track spares is undertaken, and (2) the manufacturing activities of spares are allowed to be undertaken at a relatively constant level throughout the production period.[70] Even at current volumes, the track production industry is struggling with marginal profits and in many cases experiencing losses because most worn track is refurbished at Army depots and reissued back to the tank fleet rather than discarded, making new track procurement necessary only for new tanks.

g. Donaldson Company and United Air Cleaner Company

Donaldson Company and the United Air Cleaner Company are the only produces of air filters for the Abrams tank. The air filter is a non-repairable component which cleans the ambient air prior to entry into the engine and is critical to engine performance. The Abrams tank utilizes three air filters or V-packs.

(1) Donaldson Company. The Donaldson Company maintains four percent of its business with DOD contracts and the remaining 96 percent in commercial sales. Donaldson has the capability to produce 5800 air filters per month but is currently

[70]Gutmanis, p. 109.

operating at two percent capacity with direct sales to GDLS at 100 air filters per month. Facing a slowdown or complete production termination, Donaldson is planning to dissolve its Abrams air filter production line.

(2) United Air Cleaner Company. The United Air Cleaner company maintains 80 percent of its business with DOD contracts and the remaining 20 percent in commercial sales. United Air Cleaner Company has the capability to produce 2240 air filters per month but is currently operating at 77 percent capacity with direct sales to GDLS at 1728 air filters per month. Since the current contract is about to expire and there are no new contracts pending for air filters with United Air Cleaner Company, it is planning to dissolve its Abrams air filter production line.

With the Donaldson and United Air Companies both about to exit the Abrams air filter production, the production base will erode, although a four- to seven-year supply of air filters exists. Only continued production of tanks or a stepped up demand for spares will enable both firms to remain in this production sector. This will become critical to sustaining the operational fleet in the future, especially if tanks are once again deployed to harsh desert environments where consumption of air filters is high causing unforecasted demands.

h. Bendix Corporation

Bendix, Engine Controls Division, manufactures the starter for the Abrams at two facilities. The hydromechanical components are produced in Rocky Mount, North Carolina by 20 personnel and the electronic components are produced in

San Diego, California by 130 personnel. Annual starter production has been 900 units. Bendix also manufactures commercial starters and other types of electronic controls for General Electric, Allison, and other firms. Abrams work constitutes 50 percent of Bendix business.

Bendix relies on over 20 third- and fourth-tier subcontractors for its components but none of these vendors are unique because many of the components for the starter have civil applications as well as military applications. Starter technology has advanced primarily from analog to digital technology and some modernization in manufacturing processes has taken place. The number of firms capable of producing the starter for the tank are numerous should Bendix exit starter production. Therefore, sustaining this segment of the tank industrial base does not seem to be an issue.

i. Vickers Corporation

Vickers Corporation is a large industry engaged in the research and development, engineering, and production of hydraulic pumps for numerous weapons systems and commercial applications. The manufacture of hydraulic pumps involves three metal forming operations: casting, forging, and machining. Annual production of Abrams pumps is 750 units which represents about 2 percent of total Vickers production.

The technology used in hydraulic pumps is advanced, but the hydraulic pumps used on the Abrams do not utilize this technology For example, tank hydraulic pumps are designed for a pressure of 3000 psi, whereas a number of other hydraulic pumps manufactured by Vickers exceed 8000 psi.[71] Additionally, the tank hydraulic pump is almost identical to civilian pumps. Pump manufacture utilizes advanced production processes, so in order to stay competitive, Vickers has kept the most advanced production techniques on the Abrams production line in order to improve quality and ensure production efficiency. Vickers has few outside vendors so it does not need to sustain a third- or fourth-tier subcontractor base.

It is expected that Vickers will remain in business regardless of decisions affecting the outcome of future tank production. Should Vickers choose to leave Abrams hydraulic pump production, there are at least 20 or more vendors who can manufacture pumps for the Abrams.

D. SUMMARY OF THE TANK SUBCONTRACTOR BASE

As stated earlier in this chapter, the subcontractor base for the Abrams tank contains firms ranging from those totally dependent on tank production for survival to multiproduct firms manufacturing components and end items for both DOD and commercial markets. The technologies between the five industrial segments vary from complex electronics and optics to bulk steel plate production influencing factors such as production lead times, personnel training and qualification, and manufacturing equipment and processes.

The options available to DOD, Congress and industry for preserving the tank industrial base will affect the subcontractor base in the following ways.

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[71]Gutmanis, p. 114.

1. **OPTION ONE: The Army should mothball the Lima, Ohio tank plant after the last Abrams tank is built.**

This plan would include a complete layaway of LATP, extensive employee layoffs and termination of tank production. The industrial facilities utilized by GDLS would be retained and equipment stored in place.

At the subcontractor level, tank production termination would break up the tank industrial base in its current configuration. The complex machining industrial segment, which is run by GDLS, would close with LATP's closure. The loss of skills and production processes along with advances in production technology would be lost in the complex machining segment.

The basic materials industrial segment would be devastated with the loss of the sole DU facility in the U.S. The armor steel plate and steel casting firms would leave DOD business entirely with no guarantee of their return in the future.

The electro-optical segment would be hardest hit at the third- and fourth-tier subcontractor level where many firms at this level are firms totally dedicated to making one-of-a kind products for the second-tier tank subcontractors. At the electro-optical second-tier subcontractor level, the loss of skills and production processes for Abrams specific components would be lost but at least the skills and technologies would be maintained in other DOD and commercial contracts. Again, some of these firms would most likely exit DOD business with no guarantee of returning at a future date. Weapons manufacture at the two arsenals would likely be degraded with the loss of skills and experience that has been the characteristic of these facilities since the turn of the century.

Finally, propulsion systems would probably be least affected out of the five industrial segments with the exception of a few firms such as air filter producers, because many of the propulsion systems have commercial applications which can be transferred back to a future tank program if necessary and the military-civilian business base mix is enough to offset the loss of the Abrams program. In conclusion, the termination of Abrams production would have far-reaching and detrimental effects on the subcontractor base.

2. **OPTION TWO: The Army should reduce production to the minimum production rate that will keep the plant operational until the plant retools for the next generation tank.**

This option is based on a trickle production rate which sustains a minimal production process, critical equipment and skills and provides for an orderly expansion to full-rate production in an emergency. The analysis suggests that with a few exceptions, the tank subcontractors will remain viable industrial entities and will be able to provide products and services for the Abrams program if the minimum production rate is ten tanks per month. Specific firms that expect to suffer with trickle rate production are Goodyear (track), Donaldson (air filters), Hughes (TIS/LRF), and GDLS (complex machining).

At the second-, third-, and fourth-tier levels, the type of component made is directly related to the business decisions being made regarding trickle production. The firms that favor trickle production manufacture products that are similar to goods manufactured for other DOD systems and commercial products while those opposed to trickle production are totally reliant on Abrams production. Those firms that exit Abrams component production due to uneconomical production rates will have to be replaced, and the effects on sensitive industrial segments such as electro-optics will be that significant delays of one to two years will be experienced for personnel training, equipment installation, testing, etc., before an adequate supply of these advance products can be obtained from new suppliers. If new suppliers do not have the opportunity to advance along the learning curve via significant production experience, the feasibility of obtaining these products may be hindered.[72]

Most subcontractors fear that production rates below ten tanks per month will result in erosion of technical personnel and a low return on their capital equipment resulting in closure of the production line. Also, the fixed overhead costs would have to be allocated to fewer production units forcing per unit prices for tanks to be raised. This will likely be difficult to execute in the current budget climate. From the contracting aspect, the lower rates leading to higher per unit costs would force contract renegotiations at all tiers of the tank industrial base for products and services. The end result would be increased per unit costs for the tank.

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[72]Gutmanis, p. 54.

3. **OPTION THREE: The Army should complete production of the M1A1 tank and then use the factory to retrofit/upgrade older model tanks to the M1A2 tank.**

This option bridges the M1/M1A1 to the Block III tank by incorporating emerging technologies into the M1A2 or Block II tank. With minor exceptions, this is the most preferred option for the subcontractor base because it maintains the tank industrial base in its current configuration. The engine-Textron and transmission-Allison manufacturers will be forced to reduce operations because the M1A2 program will utilize refurbished M1/M1A1 hulls and propulsion systems although there will still be a spares requirement. Since Allison dominates the world's transmission market and Textron has 35 percent of its business in commercial markets, this reduction should not affect their business base and will allow them to surge production in the event of an emergency.

The remaining second-, third-, and fourth-tier subcontractors can continue production, incorporate new technologies in the tank components, and refine manufacturing processes. The result is that an established tank industrial base will enable the U.S. to provide the most advanced tank in the world to the U.S. Army and will also enable DOD to sustain the necessary infrastructure required to develop and field future main battle tanks.

In conclusion, the course of action which best preserves the subcontractor base is Option Three. Trickle rate production in Option Two would steadily erode the tank industrial base resulting in slow elimination of the tank industrial base over time. Tank production termination in Option One would cause irrevocable damage to the subcontractor base and limit future options available to DOD, Congress and industry for preserving the tank industrial base and developing future armored weapons systems.

VI. MOBILIZATION AND SPARE PARTS

A. INTRODUCTION

The purpose of this chapter is to analyze mobilization and spare parts issues as they apply to the tank industrial base and relate the three options for preserving the tank industrial base to these issues.

B. MOBILIZATION OVERVIEW

Mobilization in World War II was best characterized as a "short-range problem motivated by large-scale combat."[73] This conception of the mobilization process assumed that the industrial base would be capable of rapidly converting into an arsenal of democracy and thus became a component of U.S. national security strategy during the Cold War years. But this conception was changed when President Reagan, in his 1988 national security strategy report to Congress, stated that mobilization was only a supporting capability for deterrence and the flexible response strategy.[74] This interpretation of mobilization was further solidified when the Soviet Union and Warsaw Pact were dissolved and the U.S. now faced potentially varied threats with different capabilities around the world. Regardless of the type of threat, the mobilization planning

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[73]James Blackwell, *Deterrence in Decay: The Future of the U.S. Defense Industrial Base*, The final report of the CSIS Defense Industrial Base Project, Washington, D.C.: Center for Strategic and International Studies, May 1989, p. 11.

[74]Blackwell, p. 10.

process consists of a variety of activities, the first of which is the development of specific policies for the conduct of the industrial preparedness program.

1. The Mobilization Process

The industrial preparedness planning process consists of a variety of activities, the first of which is the development of specific policies for the conduct of the industrial preparedness program. The Defense Guidance from the Secretary of Defense generally establishes a policy for the conduct of the industrial preparedness program. Each year, the Unified and Specified Commanders submit a list of critical weapon systems and components to the Joint Staff. This data is used to develop a single prioritized list of critical weapon systems and components (CINC CIL). Each military Service then develops its own annual list of critical weapon systems and components, based in part on the data provided by the Joint Staff. The Services' selections are then incorporated into the Industrial Preparedness Planning List (IPPL).

a. Industrial Preparedness Planning List

The IPPL is divided into two sections. Major weapon systems such as tanks are listed in Section I while major components such as engines are listed in Section II. The components requiring vertical planning are listed under the appropriate weapon system or end item, and those common to more than one system are so identified. The IPPL also lists the end user and DOD organization responsible for the specific industrial preparedness planning. Each service must submit its IPPL to the Deputy Undersecretary of Defense for Industrial and International Programs and the Defense Logistics Agency

(DLA), which then develop their own IPPL. The weapon systems and components listed are included in surge and mobilization plans.

b. *Objectives of Mobilization Planning*

The objectives of mobilization planning are to realistically plan the total requirement for post-mobilization day (M-day) production of the critical weapon systems and items listed in the IPPL and identify planned emergency producers. The planning can be accomplished by any one of four methods. They are (1) DD Form 1519, (2) Data Item Description (DID), (3) Direct Industrial Base Plan (DIBP) and (4) special studies.[75]

The DD Form 1519 method is used to accomplish production planning with firms that have voluntarily entered into the Industrial Preparedness Planning Program (IPPP). This method begins with the acquisition activity or applicable program office determining the total planning requirement for a specific weapon system or component through the use of production planning schedules that are verified by the Armed Services Procurement Planning Officer (ASPPO) and the firm's Industrial Plant Representative (IPR). This verification, along with a plant survey, is recorded on DD Form 1519, down through subcontractor level. The program office or acquisition activity then reviews all proposed industrial preparedness measures and communicates the disposition of the proposals to the planned producer through the ASPPO.

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[75]Defense Systems Management College, *Integrating Industrial Preparedness Into the Acquisition Process, A Guide for Program Managers*, First Edition, Fort Belvoir, VA: DSMC, April 1989, p. 4-2.

The DID method is executed through DOD contracts since most contracts mandate that information be provided to the acquisition activity or program office pertaining to industrial preparedness. Acceptance of the DID is a contractual obligation. The acquisition activity or program office must specify the required level of surge and mobilization production and necessary overall planning to execute the surge or mobilization. A contractor becomes a planned producer by executing the agreement contained on the DD Form 1519 under the DID method. The ASPPO will allocate plant capacity on the basis of the response to the DID requirement.

The acquisition activity or program office may choose to conduct industrial preparedness planning directly with a selected prime contractor instead of having to go through the ASPPO. This method is known as the DIBP method and under this method, the acquisition activity performs the functions of the ASPPO.

The last mobilization planning method is the execution of special studies. DOD components may choose to gather industrial preparedness data by simply conducting a special study. At the conclusion of the study the facility ASPPO, with concurrence of the acquisition activity or program office, coordinates plant capability allocation and completes plant loading records.

c. *Objectives of Surge Planning*

Surge planning consists of an in-depth assessment of the cost and effort required to rapidly increase peacetime production rates within the limits of the contractor's existing operations. In the case of the Abrams tank, the surge rate is 120 tanks per month from a current 20 tanks per month. During Desert Shield/Storm, tank production did not surge although many tank subcontractors were required to surge production in order to meet the increased demand in spare parts for the operational tank fleet. The surge effort identifies actions required to ensure significant production rate increases within six months for consumables and within twelve months for major weapons systems.

The surge planning process includes, but is not limited to, an examination of the need for long lead time components, special tools and test equipment, component prefabrication, skilled manpower, and storage space to store long lead time and prefabricated components. Production plans are updated annually for surge items on the IPPL or when requirements change significantly. Plans for all other items are updated every two years.

Policy development is followed by the selection of the items and weapon systems that will be included in the preparedness plans, as well as identifying the planned producers of the systems. Government and industry planners, the Armed Services Production Planning Officer (ASPPO) and the Industrial Preparedness Representative, respectively are then assigned to those systems and industrial facility surveys are conducted.

Execution of mobilization and surge plans is governed through the concept of Graduated Mobilization Response (GMR). The GMR concept suggests actions and options that should be considered in a given crisis stage. This concept does not replace the numerous mobilization policies, plans and laws in place but provides a framework into which many different actions that may be performed by different agencies can be inserted to check for logic, sequencing, and similar matters.[76] The GMR program is based on a concept described by the term Industrial Alert Condition (INDCON). This concept was envisioned as a shorthand description for a large number of different emergency measures that increases industrial responsiveness or reallocates manpower resources and "suggests actions and options that should be considered at each crisis stage."[77] The INDCON levels progress from basic peacetime level through surge and total mobilization of national resources.

Although it is unlikely that the U.S. will undergo a total mobilization similar to the World War II experience, the likelihood of surging production to meet a contingency or short-fused crisis seems high given the nature of the current threats. Additionally, surges in production are only one step of several leading up to total mobilization. For these reasons, this analysis will emphasize surges in production rather than total mobilization.

C. SPARE PARTS OVERVIEW

Readiness and repair parts availability are interdependent and in order to ensure the capability to be flexibly responsive in a crisis, a 60-day stockage of spare parts should be maintained for the operational tank fleet. Spare parts availability for the Abrams tank is limited even though production of the tank continues. This became very clear during Desert Shield/Storm when over $105 million worth of items were pulled from General

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[76]DSMC, p. 5-2.

[77]DSMC, p. 5-2.

Dynamics Land System (GDLS) stocks scheduled for Abrams tank production in order to support the 1,904 M1A1 and 120 M1 tanks deployed in the Persian Gulf.[78] The items ranged from engines, transmissions, gunner's primary sights, thermal receiver units, electronic boxes to final drives and road wheels. Having to borrow stocks from production leaves a question concerning the capability of the war reserve to support a future contingency.

A war reserve analysis for TACOM tracked and wheeled vehicle items shows that of the required $536 million in consumable parts required to sustain the fleet in a 60-day contingency, only $96 million is funded. Table XIV shows a partial breakdown of the war reserve requirements for the tracked vehicle sector.

TABLE XIV
PARTIAL ABRAMS TANK WAR RESERVE ANALYSIS

Stock Item	Lead Time (Months) Admin + Product =	War Requirement Funded/Unfunded	War Reserve Stocks (Each) Stock On Hand/Due In
Engine	6.0 + 21.5 = 27.5	350/0	11/254
Transmission	9.0 + 15.0 = 24.0	467/0	303/164
Filters	10 0 + 11 5 = 21.5	1105/0	1105/0
Track	8.0 + 11.5 = 19.5	80214/0	58012/22202
Sprockets	1.5 + 8.0 = 9.5	642/6369	0/642
Final Drive	11.0 + 13.0 = 24.0	237/50	176/0

Source: *Military Industrial Base Sector Study.*

Table XIV indicates the total lead time (administration lead time plus plant production lead time), war reserve funding requirements, and war reserve stockage on

[78]MG(Ret) Oscar Decker, Joseph Aquino and Stephen D. Napier, *Military Industrial Base Sector Study, Tracked and Wheeled Vehicles*, Final Report from the Independent Industrial Analysis Team To Headquarters, U.S. Army Material Command, 28 April 1992, p. 14.

hand versus due in from the vendor. Lead times for these items ranged from 9.5 months for sprockets to 27.5 months for engines. Despite the fact that some items are 100 percent funded, there are actual parts shortages on hand. For example, as of April 1992, sprockets were showing 642 funded and 6369 unfunded requirements with no stocks on hand. In sum, the criticality of the war reserve stockage levels has direct impact on the readiness of the operational fleet and must be weighed against the options to preserve the tank industrial base.

D. ANALYSIS

The following discussion evaluates the three previously discussed options for preserving the industrial base with respect to surge requirements and spare parts. Figure 6 below summarizes all three options in a timeline which shows the time required to begin surge from total layaway (Option One) and time required to begin surge from the warm base (Options Two and Three). In all cases, the surge production rate is 120 tanks per month.

1. OPTION ONE: The Army should mothball the Lima, Ohio tank plant after the last Abrams tank is built.

This plan would include a complete layaway of the Lima Army Tank Plant (LATP), extensive employee layoffs and termination of tank production. The industrial facilities utilized by GDLS would be retained and equipment stored in place. At the subcontractor level, tank production termination would break up the tank industrial base as vendors seek commercial ventures to replace tank component production.

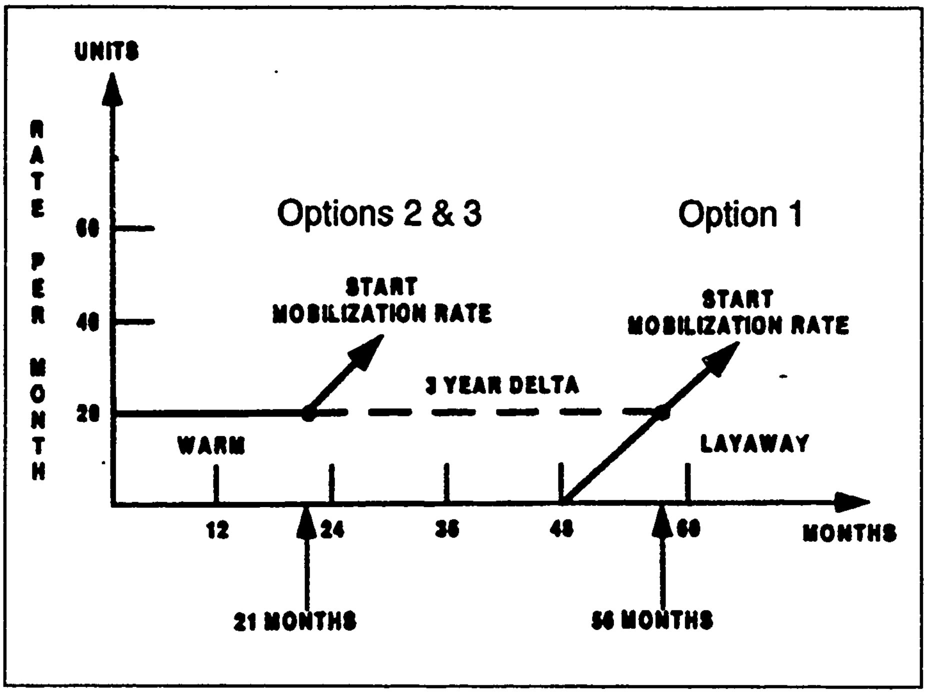

Figure 6 Production Surge to 120 Tanks
Source: Decker.

a. Surge Requirements

As stated earlier, the surge capacity for the Abrams tank is 120 tanks per month with a current production mix of 90 M1A1 and 30 M1A2 tanks. In the 1990 *Abrams Program Closure Study*, it was determined that the time to reach a surge rate from total layaway would be 51 months for the first vehicle to be produced and 72 months for the surge rate to be attained. This assumes that the Depleted Uranium (DU) facility is closed for more than two years since the restart efforts beyond the two year mark are significantly higher. A more detailed discussion of the two-year breakpoint is discussed in detail in Chapter IV. Should the surge requirement be executed if the DU facility is closed less than two years, the time to reach a surge rate from total layaway would be 33 months for the first vehicle to be produced and 56 months for the surge rate to be attained.

b. Spare Parts

The biggest disadvantage from total layaway of the tank industrial base is that the critical back up for Class IX spares will not exist. Desert Shield/Storm has already shown that Abrams funded and on hand stocks, as well as war reserve stocks, were not adequate to support the Abrams fleet deployed in the Persian Gulf. Additionally, since the layaway scenario shows a response time of 72 months to attain a surge rate, the sub-sector suppliers will require "at least 48 months to fill the pipeline, (plant management to qualify vendors, vendors to order material, vendors to produce First Article Test (FAT) pieces, evaluate and pass FAT), and finally start production to fill their plant pipeline."[79] The 1990 *Abrams Program Closure Study* estimated that the spares pricing would rise between 50 percent and 100 percent of the original cost in a total layaway scenario because some subsectors would become totally reliant on spares production once vehicle production ended. Without a warm tank industrial base, parts availability can evolve into a major logistical crisis unless there are adequate war reserve stocks. Since the war reserves are already lacking, it will be difficult to reach 100 percent war reserve stockage levels due to normal operating and maintenance demands.

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[79]Decker, p. 9.

2. **OPTION TWO: The Army should reduce production to the minimum production rate that will keep the factory operational until the factory retools for the next generation tank.**

This option is based on a trickle production rate which sustains a minimal production process, critical equipment and skills, and provides for an orderly expansion to full-rate production in an emergency. In this case the minimal production rate is ten tanks per month.

a. Surge Requirements

In the 1990 *Abrams Program Closure Study*, it was determined that the time to reach a surge rate from a minimum production rate of ten tanks per month would be 22 months for the first vehicle to be produced and 47 months for the surge rate to be attained. This surge capability is significantly better than that found in Option One since production processes, critical equipment, critical skills, and certifications are already in place allowing for a more efficient expansion to full-rate production.

b. Spare Parts

The advantages of maintaining a warm base are that spare parts and assembly production are available in an emergency and lead times are reduced since continued production eliminates all the requirements to qualify vendors and conduct FAT tests on components and assemblies. The 1990 *Abrams Program Closure Study* estimated that spares pricing would rise between 25 percent and 50 percent of the original cost in a minimum production scenario because some subsectors would be more reliant on spares production once vehicle production was reduced.

3. **OPTION THREE: The Army should complete production of the M1A1 tank and then use the factory to retrofit/upgrade older model tanks to the M1A2.**

This option bridges the M1/M1A1 to the Block III or Future Main Battle Tank (FMBT) by incorporating emerging technologies into the M1A2 or Block II tank. The reconversion rate is 20 tanks per month.

a. Surge Requirements

In the 1990 *Abrams Program Closure Study*, it was determined that the time to reach a surge rate from a normal production rate of 20 tanks per month would be 22 months for the first vehicle to be produced and 45 months for the surge rate to be attained. The differences between the minimum sustaining rate found in Option Two and the normal production rate in this option are marginal. In fact, normal production rates of 30 tanks per month to the surge rate of 120 tanks per month are 21 months to the first vehicle and 40 months for the surge rate to be attained. Again, the key factor in this option is that production processes, critical equipment, critical skills, and required certifications are already in place, allowing for a more efficient expansion to full-rate production.

b. Spare Parts

As described in previous chapters, it is more economical to produce tanks at rates of 20 per month than in lesser numbers. For example, in FY94, the cost of ten M1A1 tanks with no production of M1A2 tanks would be $6.6 million per unit. But if 10 M1A1s and 20 M1A2s were built in FY94, the cost per M1A1 would drop to $3.9 million each and the cost of the M1A2 would be $5.3 million per unit. This drop in per unit costs would be reflected in the corresponding prices for spare parts. As stated earlier, spares pricing when no tank production is taking place would be 50 to 100 percent above spares pricing during normal production, while spares pricing at trickle rate production would be 25 to 50 percent above normal production spares pricing.[80] Again, the advantages of maintaining a warm base are that spare parts and assembly production are available in an emergency and lead times are reduced since continued production eliminates all the requirements to qualify vendors, and conduct FAT tests on components and assemblies.

E. SUMMARY

Of the three options to preserve the industrial base, the best option is to maintain a warm base by either executing Option Two or Option Three. Of these two options, the 20 tanks per month production/conversion rate to the M1A2 is better, since normal production is economically better than trickle rate production. Option Three and Option

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[80]U.S. Army Tank-Automotive Command, *Abrams Program Closure Study*, Warren, MI: Unpublished Slides, September 1990, Slides ICC 19.2, ICC 15.6.

Two give the tank industrial base a better capability to surge production in an emergency by surging production from 21 months to full-rate production at 45 months. Surge rates from total layaway would require 51 months to the first tank and 76 months to full-rate production.

Spare parts availability are severely impacted by total layaway. Given the criticality of spare parts on hand and war reserves, total layaway would place the readiness posture of the operational tank fleet in jeopardy especially should another Persian Gulf scenario take place. Again, it would be best to execute reconversion to the M1A2 in order to keep spares prices in check and insure adequate stockage of parts on hand.

From a surge and mobilization standpoint, it is critical that the industrial base be preserved. Concurrently, a spares inventory and war reserve capability must be maintained to sustain the operational tank fleet and enable the armor force to support itself in a short-fused crisis situation. By maintaining a warm base, the flexibility remains to execute responsive production surges while supporting the existing armor force.

VII. OPERATIONAL EFFECTIVENESS CONSIDERATIONS

A. INTRODUCTION

While Chapter IV examined the options available to DOD, Congress, and industry to preserve the industrial base from a cost aspect, the purpose of this chapter is to address the issue from an operational effectiveness viewpoint.

The criteria used to evaluate the operational effectiveness of each option for preserving the tank industrial base include: (1) force mix and structure, (2) technological superiority, (3) logistical support requirements, (4) training and doctrine, and (5) Foreign Military Sales (FMS).

B. EFFECTIVENESS ANALYSIS

This section addresses the factors of operational effectiveness, through each of the three previously discussed options to preserve the tank industrial base, and how the factors are directly influenced by the three options.

1. OPTION ONE: The Army should mothball the Lima, Ohio tank plant after the last Abrams tank is built.

This plan would include a complete layaway of Lima Army Tank Plant (LATP), extensive employee layoffs and tank production termination after the first phase of the M1A2 retrofit is completed in 1995. The industrial facilities utilized by General

Dynamics-Land Systems Division (GDLS) would be retained and equipment stored in place.

a. Force Mix and Structure

The force mix and structure is marginally impacted by the addition of 272 M1A2 tanks to the armor force because these 272 tanks would only comprise 3.3 percent of all tanks in the inventory. These M1A2s would equip between four to five armor battalions of 58 tanks each or roughly 1.5 heavy divisions. These numbers do not account for tanks that would be required for overseas prepositioning, maintenance float vehicles, and training tanks for the Armor School, etc. In this case, actual deployable numbers in the field would even be lower.

Additionally, the Army has implicitly designated the 2164 M1 105mm Abrams tanks as a tank of last resort. During Desert Shield, the Army chose to transition almost all of the M1s in the Persian Gulf to the M1A1 up to the day that the ground offensive was launched by the coalition forces. The next war will probably see few if any M1 or M1IP tanks in combat, with the preponderance of the armor force being M1A1's.

b. Technological Superiority

The Army's modernization strategy is compromised because production termination after the initial reconversion program will give some potential adversaries superior weapon systems compared to those held by the U.S. At least 59 percent of the armor force will have the M1A1 with only four percent possessing the M1A2, resulting in the bulk of the front-line or forward deployed armor force being equipped with the M1A1. Examples of this technological gap are already evident as the U.S. Government has approved the sale of 760 M1A2s to Kuwait and 700 M1A2s to Saudi Arabia and several European allies and Japan are marketing equal or potentially better tanks to various other nations.

c. Logistical Support Requirements

In addition to the costs required to manage the tank industrial base, it is important to note that the majority of the operational Abrams fleet is already between 10 and 15 years old and that increased Operation & Maintenance (O&M) funds will be required to sustain this fleet as it ages if no new or refurbished tanks are fielded after 1995. The force mix given production termination is contained in Table XV.

TABLE XV
ABRAMS FORCE MIX

Option	M1	M1IP	M1A1	M1A2	Total
Production Termination in 1995	2164	894	4802	272	8132
Full Upgrade	1372	894	4802	1064	8132

Source: GDLS.

This mix would require a spare parts and maintenance base for 272 M1A2s in the Army's inventory. This would likely contribute to higher O&M costs because the spare parts demands for such a small number of systems would be difficult to track especially if the tanks were geographically scattered around the United States or deployed overseas. It would also place a burden on industry as they would be required to produce small amounts of spares at less than economical rates to sustain this M1A2 fleet. Table XV does not account for the estimated 5000 M60 tanks still in the Army's inventory. Four different Abrams variants, along with the M60 fleet, would approximate the logistical challenge faced by the German Army during World War II as it supported an armored force with a multitude of armored platforms, each with many variants. Again, this expanded logistical tail to support 272 M1A2 tanks will probably result in higher O&M costs.

The majority of the armor force will have M1A1 tanks which in the past have been difficult to transport and recover due to their 67 ton weight using the existing Heavy Equipment Transporters (HET) and M88-series tracked recovery vehicles. The M1A2 will weigh 68.5 tons which makes HET transportability and tank recovery more difficult. This will require faster deployment of new generation support vehicles to support the 272 M1A2s that will be in the armor force.

d. Training and Doctrine

If production terminates after 272 M1A2 tanks are fielded to the U.S. Army, questions to consider are how efficient will it be to train tank crewmen to operate a relatively unique system? Will a Military Occupational Specialty (MOS) Additional Skill Identifier (ASI) be required for M1A2 crewmen and maintenance personnel (turret mechanics)? How will doctrine and tactics be rewritten to incorporate the superior C^3 and fire control capabilities of the tank since these capabilities will exponentially increase the commander's ability to quickly develop the battle utilizing the Commander's Integrated Display (CID)? These questions mean that the small percentage of the armor force will be trained on the M1A2 and that a transition program will have to be established by the Armor School in Fort Knox, Kentucky, to train personnel being assigned to M1A2 equipped units.

An additional issue to consider with the small number of deployed M1A2s is the number of Unit-Conduct-of-Fire Trainers (UCOFT) tank simulators that will be required for each M1A2 battalion. To purchase one for each battalion plus an additional one at the Armor School will add up to five or six simulators for the Army. At these low rates, per unit costs of each simulator and required contractor support will probably be much higher than if a larger M1A2 force were fielded.

e. Foreign Military Sales

The lack of commitment to tank production by the U.S. erodes the FMS business base because production termination also adds to the per unit costs for FMS. This would motivate foreign customers to seek out other types of tanks, resulting in further degradation to the tank industrial base as the business base is eroded. Japan, France, Germany, and the United Kingdom are already entering production for domestic and foreign customers with new model tanks which would take potential business away from the U.S.

2. **OPTION TWO: The Army should reduce production to the minimum production rate that will keep the factory operational until the factory retools for the next generation tank.**

This option is based on a trickle production rate which sustains a minimal production process, critical equipment and skills and provides for an orderly expansion to full-rate production in an emergency.

a. Force Mix and Structure

This option is similar to Option One in that trickle rate production of the M1A2 would eventually reach numbers similar to production termination in 1995. Again, the force mix and structure would be marginally impacted by the addition of 272 M1A2 tanks to the armor force because these 272 tanks would only comprise 3.3 percent of all tanks in the inventory. These M1A2s would equip five armor battalions of 58 tanks each or roughly 1.5 heavy divisions. These numbers do not account for tanks that would be required for overseas prepositioning, maintenance float vehicles, and training tanks for the Armor School, etc. As in Option One, the actual deployable numbers in the field would even be lower.

As in Option One, the Army has implicitly designated the 2164 M1 105mm Abrams tanks as a tank of last resort. The next war will probably see few if any M1 or M1IP tanks in combat with the preponderance of the armor force being M1A1s.

b. Technological Superiority

Although this option preserves the industrial base in its current configuration, this implies that the leading units of the armor force will continue to possess tanks based on 1970's technology that are being matched or exceeded by potential adversaries. This would violate the Army's modernization strategy because potential adversaries would have a superior weapon system compared to that of the U.S. Examples of this technological gap abound as the U.S. Government has approved the sale of M1A2s to various nations to include Saudi Arabia and Kuwait and perhaps the United Kingdom, United Arab Emirates, Canada and Pakistan.

c. Logistical Support Requirements

The force mix given production slowdown could eventually reach the mix attained in the production termination force mix, (Table XV) concluding the first phase in the reconversion program. This mix would require a spare parts and maintenance base for 272 or fewer M1A2s in the Army's inventory, most likely contributing to higher overall O&M costs. The spare parts demand for such a small number of systems would probably be difficult to track especially if the tanks were geographically scattered across the United States or overseas. It would also place a burden on industry as they would be required to produce small amounts of spares at less than economical rates, with costs being passed on to DoD and further eroding the subcontractor base. As in Option One, the weight of the M1A2 will force the Army to accelerate the deployment of new generation HET and recovery vehicles to support the tank.

d. Training and Doctrine

As was described in Option One, if production terminates after 272 M1A2 tanks are fielded to the U.S. Army, questions to consider are how efficient will it be to train tank crewmen to operate a relatively unique system, especially when tanks are being fielded at much slower rates due to trickle rate production?

Again, because of the small numbers of M1A2s in the armor force, fewer crewmen and mechanics will have to be trained on the tank, only selected officers would be taught M1A2 specific doctrine and tactics, and small numbers of UCOFT tank simulators procured. Such minimal amounts of support will most likely be at less than economical rates.

e. Foreign Military Sales

As in Option One, the lack of commitment by the U.S. to tank production erodes the FMS business base because production termination adds to the per unit costs for FMS sales. This would motivate foreign customers to seek out other types of tanks, resulting in further degradation to the tank industrial base as the business base is eroded. Japan, France, Germany, and the United Kingdom are already entering production for domestic and foreign customers with new model tanks which would take potential business away from the U.S.

3. OPTION THREE: The Army should complete production of the M1A1 tank and then use the factory to retrofit/upgrade older model tanks to the M1A2.

This option bridges the M1/M1A1 to the Block III or Future Main Battle Tank (FMBT) by incorporating emerging technologies into the M1A2 or Block II tank. It is a cost effective option because at two-thirds the cost of a brand new M1A2, an older tank is converted into the most technologically advanced tank in the world.

a. *Force Mix and Structure*

Table XV depicts the force mix under the full retrofit program. The bulk of the armor force would consist of M1A1s and M1A2s, simplifying logistics since larger numbers of M1A2s would now be in the inventory and easier to track and manage. This force mix also gives the Army the necessary firepower to counter existing threats.

b. *Technological Superiority*

This option incorporates leap-ahead technologies that overmatch any potential adversary and most importantly, gives the soldier a technological advantage over a potentially numerous foe. This option is in line with the Army's modernization strategy and at the same time preserves the tank industrial base.

c. *Logistical Support Requirements*

This mix would require a spare parts and maintenance base for 1064 M1A2 tanks under the full upgrade plan presented in Table XV. This creates a larger base for spares procurement, distribution and maintenance. It also allows industry to produce spares at economic orders of quantity (EOQ) and allows better tracking of parts through the supply system. Again, four different Abrams variants, along with the M60 fleet, would still give Army quartermasters and ordnance personnel a major logistical challenge since so many parts between tank variants are incompatible.

Other aspects to consider are the M1A2's weight, which requires improved HET and maintenance/recovery vehicle capabilities. The M1 weighs 60 tons, the M1A1 weighs 67 tons, and the M1A2 weighs 68.5 tons. The Army's ability to transport tanks long distances and recover them in the battlefield was already identified as a serious shortcoming during Desert Shield/Storm. Under this option, the higher mix of M1A1s and M1A2s equates to more tanks with greater weight in the armor force. Therefore, priority will have to be given to speeding up the development and fielding of the HET capabilities for these weapon systems.

d. Training and Doctrine

From a training and doctrine standpoint, new tactics will be required incorporating the M1A2's superior fire control system and command, control communications capabilities (C^3).[81] Additional operations and support costs will have to be dedicated to training the tank crewmen and maintenance personnel required to operate and maintain the M1A2 since the M1A1 and M1A2 are technologically a generation apart. Along with the fielding of M1A2s, the UCOFT and other tank crew simulators will be required to support training on the weapon system.

[81]Neil Munro, "'Kick-ass Tank,' M1A2 Struts Stuff at NTC But Glitches Plague Debut," *Army Times*, 5 October 1992, p. 35.

e. Foreign Military Sales

The approved sale of M1A2s to various countries would in some cases assure system compatibility with U.S. systems, particularly in the Middle East. Per unit costs of FMS tanks are also lowered, since production of U.S. and foreign tanks now takes place, distributing overhead across a greater number of tanks in production.

C. SUMMARY

From an operational effectiveness approach, the best option is to continue the full retrofit program for the M1A2 tank (Option Three). This gives the higher percentage of M1A2s (13.1 percent) to the armor force with the majority of the fleet possessing the M1A1 (58.9 percent). This is a much better force mix than that of Options One and Two. With 13.1 percen he armor force possessing a tank with advanced technology, the Army's front-line units will have a decisive technological advantage over any enemy on the battlefield.

Logistics support will be easier to manage for a larger fleet than for a smaller fleet of tanks. Additionally, utilization of M1 Abrams tanks for reconversion results in fewer older tanks in the force. This equates to lower operations and maintenance costs to support first-generation tanks. The major disadvantage of Option Three is that to support the 1064 M1A2s in the fleet, priority will have to be given to deploying new generation HET and tracked maintenance recovery vehicles to support the tanks. Without this, the M1A2 will be hindered by a lack of adequate transport and recovery capability.

In some cases, approved FMS of M1A2s to various countries would result in system compatibility with U.S. systems, simplifying combat logistics. This is especially applicable in the Middle East.

In conclusion, continued retrofit to the M1A2 will give operational commanders a decisive technological edge over any enemy while preserving the tank industrial base.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. GENERAL CONCLUSIONS

The tank industrial base is unique and essential to the readiness of the U.S. Army. There is no commercial counterpart. The world is becoming more unstable and the need for U.S. peacekeeping strength is greater than ever. To let the tank industrial base whither due to an unclear industrial base plan is to compromise future readiness, tank program options, and U.S. resolve to support its allies.

In the FY93 DOD budget, Congress appropriated $161 million to upgrade 210 older M1 105mm tanks to the M1A2. With the addition of the $197.4 million obtained from the sale of tanks from the Army inventory in FY91/92 and the $225 million appropriated in FY92, the survival of the tank industrial base through at least 1995 seems secure[82]. As stated in a recently published Congressional Budget Office (CBO) study, "the Congress opted to insure against possible future threats to U.S. security by sustaining most of the tank industrial base."[83]

From a cost effectiveness analysis, the recommended option for preserving the tank industrial base is Option Three (Full Upgrade). The challenge now lies in obtaining the

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[82]U.S. Congress, House of Representatives, *Department of Defense Appropriations Bill, 1993*, Report 102-627 to Accompany H.R. 5504, 102nd Congress, 2nd Session, 29 June 1992, p. 86.

[83]U.S. Congress, Congressional Budget Office, "Alternatives For The U.S. Tank Industrial Base," A CBO Study, February 1993, p. 36.

three billion dollars necessary to complete the second phase of the reconversion program, the retrofit of an additional 792 tanks to the M1A2, scheduled to take place between 1996-1999. At the conclusion of the retrofit program in 1999, a total of 1064 M1A2 tanks could be part of the armor force.

B. SPECIFIC CONCLUSIONS

The following conclusions summarize the advantages and disadvantages of each of the three options for preserving the tank industrial base within the scope of this thesis. This summary is followed by a comparative analysis of the three options.

1. Summary of Options for Preserving the Tank Industrial Base

The following three options are among several that DOD, Congress, and industry have proposed and will continue to be debated in the coming years.

a. OPTION ONE: The Army should mothball the Lima, Ohio tank plant after the last Abrams tank is built.

This plan would include a complete layaway of Lima Army Tank Plant (LATP), extensive employee layoffs and tank production termination after the first phase of the M1A2 retrofit is completed in 1995. The industrial facilities utilized by General Dynamics-Land Systems Division (GDLS) would be retained and equipment stored in place. Advantages of executing this option are that:

- There are over 8000 Abrams tanks in the Army inventory, so the military does not require any more tanks.
- Current FMS and the Heavy Vehicle Assault Bridge program will provide enough work to sustain the tank industrial base.

- Phase I of the retrofit program links the M1A2 to the Future Main Battle Tank (FMBT), sustaining the design, development, production expertise and Abrams program experience through at least 1995.

- The M1A1 is fully capable of maintaining its role as the most lethal tank in the world based on the Desert Storm experience. Therefore, more M1A2's beyond 1995 are not needed.

Disadvantages of executing this option are that:

- Upon closure, the tank industrial base will permanently lose the design, development, production expertise and Abrams program experience.

- Closure costs are estimated at $569.4 million with an additional one billion dollars required to restart production from total layaway.

- After Phase I of the retrofit program is completed, spare parts prices will increase between 50 and 75 percent of the original price.

- After closure, the ability to expand in an emergency under surge or mobilization scenarios will be critically hampered.

- The Army's modernization strategy is nonexistent with a cold tank production base.

- Upon closure, industry will be unable to refine its production processes through the maintenance of a warm production base.

- Upon closure, the majority of subcontractors will permanently exit tank production.

- Various foreign countries will possess the M1A2, while the majority of U.S. forces will possess the M1A1.

- The uncertainty surrounding the development, production and fielding of the Future Main Battle Tank (FMBT) could potentially leave U.S. forces with the Abrams for the next twenty or more years.

- Closure will terminate depleted uranium armor production for the Abrams tank which significantly enhances crew survivability.

b. ***OPTION TWO: The Army should reduce production to the minimum production rate that will keep the factory operational until the factory retools for the next generation tank.***

This option is based on a trickle production rate which sustains a minimal production process, critical equipment and skills and provides for an orderly expansion to full-rate production in an emergency. Advantages of executing this option are that:

- Phase I of the retrofit program links the M1A2 to the Future Main Battle Tank (FMBT), sustaining the design, development, production expertise and Abrams program experience through at least 1995.
- The retrofit program maintains the repair parts supply base and gives DOD the ability to expand in an emergency under surge or mobilization scenarios for the near-term.
- The M1 conversion program allows the Army to support an ongoing modernization strategy in a cost effective manner through the execution of technology insertions into an existing weapon system.
- The continuation of the retrofit program allows industry to refine its production processes through the maintenance of a warm production base with improved technology upgrades on the assembly line.
- The retrofit program preserves U.S. capabilities to produce depleted uranium armor for the Abrams tank which will significantly enhance crew survivability.

Disadvantages of executing Option Two are that:

- It is a short-term solution to preserving the tank industrial base.
- Trickle rate production or production stretchout will steadily erode the tank industrial base, especially at the second- and third-tier subcontractor level as less than anticipated production rates force vendors out of tank component production.
- There are over 8000 Abrams tanks in the Army inventory, so the military does not require any more tanks.

- Current FMS and Heavy Vehicle Assault Bridge program will provide enough work to sustain the tank industrial base.

- The M1A1 is fully capable of maintaining its role as the most lethal tank in the world based on the Desert Storm experience, therefore the M1A2 is not needed beyond 1995.

c. ***OPTION THREE: The Army should complete production of the M1A1 tank and then use the factory to retrofit/upgrade older model tanks to the M1A2.***

This option bridges the M1/M1A1 to the Block III or Future Main Battle Tank (FMBT) by incorporating emerging technologies into the M1A2 or Block II tank. It is a cost effective option because at two-thirds the cost of a brand new M1A2, an older tank is converted into the most technologically advanced tank in the world. Advantages of executing this option are that:

- The continuation of the retrofit program links the M1A2 to the Future Main Battle Tank (FMBT) sustaining the design, development, production expertise and Abrams program experience.

- The retrofit program maintains the repair parts supply base and gives DOD the ability to expand in an emergency under surge or mobilization scenarios.

- The M1 conversion program allows the Army to support an ongoing modernization strategy in a cost effective manner through the execution of technology insertions into an existing weapon system.

- The continuation of the retrofit program allows industry to refine its production processes through the maintenance of a warm production base with improved technology upgrades on the assembly line.

- The retrofit program preserves U.S. capabilities to produce depleted uranium armor for the Abrams tank which will significantly enhance crew survivability.

Disadvantages of executing Option Three are that:

- The overall program costs are estimated at four billion dollars. Therefore, it will be difficult to fund given the current budget climate.

- There are over 8000 Abrams tanks in the Army inventory, so the military does not require any more tanks.

- Current FMS and the Heavy Vehicle Assault Bridge program will provide enough work to sustain the tank industrial base.

- The M1A1 is fully capable of maintaining its role as the most lethal tank in the world based on the Desert Storm experience, therefore the M1A2 is not needed beyond 1995.

2. Comparative Analysis

Utilizing a decision matrix to compare the three options, conclusions are attained based on the following criteria. Operational effectiveness, discussed in Chapter VII, included factors such as: (1) force mix and structure, (2) technological superiority, (3) logistical support requirements, (4) training and doctrine, and (5) Foreign Military Sales (FMS). Costs, discussed in Chapter IV, included factors such as: (1) facility layaway, (2) human resources, (3) equipment layaway, (4) equipment removal, (5) close out penalty, and (6) maintenance/caretaker costs. A relative factor ranking of both the operational effectiveness and cost factors is contained in Table XVI. It should be noted that the relative rankings indicate which option is deemed better than another option only. The rankings do not indicate how much better or worse one option is than the other.

TABLE XVI
RELATIVE FACTOR RANKING MATRIX

Criteria/Factors	Option One	Option Two	Option Three
COSTS			
Facility Layaway	3	1	2
Human Resources	3	1	2
Equipment Layaway	3	1	2
Equipment Removal	1	1	1
Close Out Penalty	1	1	1
Maintenance/Caretaker	3	1	2
OPERATIONAL EFFECTIVENESS			
Force Mix and Structure	2	3	1
Technological Superiority	2	3	1
Logistical Support Requirements	1	3	1
Training and Doctrine	2	3	1
Foreign Military Sales	2	3	1

The summary decision matrix depicted in Table XVII is a combined ranking of all the cost and operational effectiveness factors compiled from Table XVI. Again, a number one in the decision matrix reflects the best option in each category while a number three reflects the worst option.

TABLE XVII
SUMMARY DECISION MATRIX

Option	Costs	Operational Effectiveness
OPTION ONE: Production Termination in 1995	3	2
OPTION TWO: Phase I Upgrade at Trickle Rates	1	3
OPTION THREE: Full Upgrade (Phase I & II)	2	1

From a cost and operational effectiveness approach, the preferred option to take for preserving the industrial base is to continue the full retrofit program for the

M1A2 tank (Option Three). It would initially cost an estimated $154.1 million[84] to rollover to M1A2 production in 1993. By completion of the initial reconversion in 1995, this dollar amount will have become a sunk cost and for $1.4 billion the Army will possess 272 M1A2 tanks.

Option One, total production termination, is not a cost effective option. Shutting down tank production at a cost of $569.4 million and restart at a cost of $1 billion is in excess of the cost required to continue production under Option Two or Option Three.[85] In the event of a surge requirement, the cost to surge from termination would be $1.013 billion if the Depleted Uranium (DU) facility has been closed for two or more years or $948 million if the DU facility has been closed for less than two years.

Trickle rate production, as exemplified in Option Two, is less cost effective than Option Three but more cost effective than Option One. But the main concern is that a minimum production rate would increase per unit costs of the tank due to allocation of overhead to fewer weapon systems. It would force some vendors out of business if this production rate became inefficient.

By sustaining the tank industrial base under Option Three, a highly skilled and experienced workforce is retained and an established subcontractor base remains in place. The flexibility remains to execute responsive production surges while supporting the existing armor force with a warm tank industrial base. More importantly, DOD

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[84]U.S. Army Tank-Automotive Command, *Abrams Program Closure Study (Austere)*, Warren, MI: Unpublished Slides, 13 August 1991, Slide VC 13.

[85]TACOM, *Abrams Program Closure Study (Austere)*, Slide VC 10.

keeps the option to use the reconversion program as a bridge for the U.S. Army's next generation tank.

Under all options, the total armor force will stand at 8132 Abrams tanks but the Option which reflects the most lethal force mix is Option Three. In Option Three, the Army will maintain an Abrams tank force that consists of 59 percent M1A1 and 13 percent M1A2 tanks. This is a superior force mix compared to Options One and Two. Continued M1A2 conversions incorporate the latest technologies that give the Army a technological advantage over any threat. The continued conversion of older tanks to the M1A2 also supports the DOD and the Army modernization strategy which calls for existing platform upgrades as opposed to new system starts. The more balanced mix of M1A1s and M1A2s will make it easier for DOD and the Army to support the tank fleet logistically as compared to Options One and Two. In conclusion, continued retrofit to the M1A2 will sustain a unique industrial base while giving operational commanders a decisive technological edge over any enemy. Within the scope of this thesis, the preferred solution for preserving the tank industrial base after 1995 is to continue the M1A2 retrofit program.

3. Additional Conclusions

Based on the research conducted, the following additional conclusions also impact the ability of the tank industrial base to survive through the drawdown and remain viable in the future.

a. Foreign Military Sales

Foreign Military Sales (FMS) is an effective way of protecting the industrial base and reducing per unit costs to both the Army and U.S. allies. It also bridges gaps that might be created with uneven domestic tank production due to program instability in the budget cycle. It facilitates interoperability with U.S. allies since they will have similar systems in their inventory. The FMS program to allies should be pursued as a matter of military, foreign, and industrial policy at levels similar to the French or British support of their respective defense industries.

b. Regulatory Requirements

The problems generated by the declining defense budget are exacerbated by the regulations and practices associated with doing business with DOD. Furthermore, "these practices increase the cost of military systems by adding as much as 25 to 50 percent to unit costs and procurement time."[86] By adopting commercial standards through actions such as converting military specifications to non-governmental standards, adopting European vendor standards (ISO 9000) for supplier accreditation and adopting Society of Automotive Engineers (SAE) standards, some of the costly reviews and audits mandated by current government regulations are eliminated and overhead and duplication of effort reduced.

[86]U.S. Congress, Structure of the Industrial Base Panel of the Committee on Armed Services, House of Representatives, *Future of the Defense Industrial Base*, Report No. 10, 102nd Congress, 2nd Session, 07 April 1992, p. 13.

c. Subcontractor Base

The Government should continue to track and gauge the health of the second- and third- tier tank subcontractor base as the defense industry in general continues to shrink. Small businesses at the second- and third-tier levels are an integral part of technology innovation and the principal source of new jobs.[87] The Government needs to focus its attention not only on prime contractors, but the subcontractor base as well, in order to monitor the health of the tank industrial base.

d. Depleted Uranium Production

Current regulations forbid the sale of tanks with depleted uranium (DU) armor to all foreign countries. The Government should consider selling DU armor equipped tanks to selected allies if it believes that these sales will preserve the DU facility, its workforce, and manufacturing processes while not compromising national security.

e. Total Quality Management

The DOD's posture on quality states that a quality and productivity oriented defense industry is the key to DOD's ability to maintain a superior level of readiness. It further states that the emphasis must change from relying on inspection, to designing and building quality into the process and product. By incorporating Total Quality Management (TQM) into tank and tank component manufacture, the elapsed time required to perform test and evaluation procedures for tank components, which can last

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[87]U.S. Congress, *Future of the Defense Industrial Base*, p. 15.

several years in some cases, will be considerably shortened. Department of Defense test and evaluation procedures preclude further activities by firms such as full scale development until the component is accepted by DOD. By building in quality on the factory floor, the need for a lengthy and costly test and evaluation process is eliminated.

C. RECOMMENDATIONS

Within the scope of this thesis, the following recommendations are made that will ensure the long-term preservation of the tank industrial base.

1. General Recommendations

It is recommended that the second phase of the M1A2 retrofit program continue from 1996-1999 as the best course of action to maintain technological superiority, preserve the industrial base, and keep future options open to decisionmakers.

2. Specific Recommendations

Additional recommendations include:

- Increase governmental support of FMS.
- Relax regulatory requirements for contractors doing business with DOD.
- Closely track the subcontractor base during the restructuring process.
- Sell DU armor equipped tanks to selected allies as long as it does not threaten national security.
- Support TQM at all levels of the tank industrial base.

3. Recommendations for Further Research

Recommended areas for further study discussed in Chapter II may affect the options available to decisionmakers for preserving the tank industrial base and should be thoroughly examined, especially after this current round of restructuring. Research should be conducted to answer the following questions:

- Defense conversion: Can GDLS and tank subcontractors successfully transition from tank production to commercial ventures, and if so, would they be able or willing to return to tank production?
- Reconstitution: Can the tank industrial base reconstitute itself after a major downsizing in future years?
- Dual-use technologies: Can dual-use technologies be used to ease the transition from commercial production to tank component manufacture?
- Flexible manufacturing: As the production center for the Abrams tank and various other platforms built on the Abrams chassis, is it cost effective to consolidate all tracked vehicle production at Lima Army Tank Plant (LATP)?
- War reserve requirements: Realizing the costs to maintain inventory and physical and technological obsolescence of parts on hand, how can supply activities maintain an adequate war reserve stock of tank parts in order to avoid the taking of components slated for new tank production as evidenced during Desert Shield/Storm?
- Foreign investment in U.S. tank production capability: What is the level of foreign investment allowable in U.S. tank production or is government oversight on foreign investment in defense industries nonexistent? Should existing regulations be reviewed for applicability and streamlining?
- Work allocation between Original Equipment Manufacturers (OEM) and Army depots: How should tank industrial capacity be divided between OEM and depot organizations given the requirement to dismantle M1 tanks in preparation for the retrofit process?

These areas have varying degrees of significance for the tank industrial base. They all require further study to specifically assess their impact on preserving future U.S. tank production capability.

APPENDIX A: ABRAMS TANK PRODUCTION, 1980-1993

M1 Abrams: 2374
• 105mm gun with muzzle reference sensor • NBC filtration system • Chobham armor • Compartmentalized fuel and ammunition for crew protection • Halon fire extinguisher system • Digital ballistic computer • Miniaturized laser rangefinder • Thermal imaging system for day/night all-weather capability • Enhanced suspension system • AGT1500 gas turbine engine with Hydrokinetic transmission • Modular engine design • Onboard malfunction detection system • Weight: 60 tons
M1 Abrams Improved Product (M1IP): 894
• Stretch turret • Enhanced frontal armor protection • Weight: 60 tons
M1A1 Abrams: 4802
• 120mm gun with improved muzzle reference sensor • NBC overpressure system which seals crew compartment for 2.6 psi overpressure • Enhanced fire control system and digital ballistic computer • Hull and turret ammunition compartment changes for 120mm ammunition • Depleted uranium armor • CARC paint • Weight: 67 tons
M1A2 Abrams: 62
• SINCGARS radio with Radio Interface Unit (RIU) • Data bus coupler • Analog input module • Commander's independent thermal viewer (CITV) and integrated display • Survivability enhancements • Modified turret platform • Fire control electronics unit • Positional/navigational system • Improved commander's weapons station • Improved fire control system • Improved suspension system • Improved gunner's control display panel • Improved hull and turret electronics units • Driver's integrated display and thermal viewer • Weight: 68.5 tons

Source: GDLS.

APPENDIX B: DEFINITIONS

The following definitions are from the Defense Systems Management College manual, *Integrating Industrial Preparedness Into The Acquisition Process*.

1. Industrial Plant Equipment (IPE)

Industrial plant equipment is equipment used for the purpose of cutting, abrading, grinding, shaping, forming, joining, testing, measuring, heating, treating, or otherwise altering the physical, electrical, or chemical properties of materials, components, or end items entailed in manufacturing, maintenance, supply, processing, assembly, or research and development operations.

2. Other Plant Equipment (OPE)

Other plant equipment is that which is used in or with the manufacture of components or end items for maintenance, supply, processing, assembly or research and development operation; but excluding items categorized as IPE.

3. Special Test Equipment (STE)

Special test equipment consists of multipurpose integrated test units engineered, designed, fabricated, or modified to accomplish special-purpose testing in the performance of the contract. Such testing units comprise electrical, electronic, hydraulic, pneumatic, mechanical, or other items or assemblies of equipment that are mechanically, electrically, or electronically interconnected to become a new functional entity, causing the individual item or items to become interdependent and essential in the performance of special-purpose testing. Special test equipment does not include material, special tooling, and plant equipment items used for general plant testing purposes.

4. Special Tooling (ST)

Special tooling consists of all jigs, dies, fixtures, molds, patterns, taps, gauges, other equipment, and manufacturing aids that are of such a specialized nature that, without substantial modification or alteration, their use is limited to the development or production of particular supplies or parts. Special tooling does not include material, STE, buildings, general machine tools, or similar capital items.

APPENDIX C: M1A2 TANK COSTS

The following costs are estimated M1A2 specific unit costs as of February 1993.[88]

The costs exclude Non-Recurring (NR) costs, initial spares and training devices.

- **Newly Built Production M1A2 Tanks**: The total Army procurement of production M1A2 tanks (62) occurred in FY91. Deliveries are scheduled for December 1992 through April 1993. The recurring Weapon System Unit cost (WSUC) is $4.5 million.

- **Upgrade of M1A1 (Non-Depleted Uranium) Tank to M1A2**: The upgrade of an M1A1 non-Depleted Uranium (DU) armor tank to an M1A2 has a recurring WSUC of $3.2 million.

- **Upgrade of M1A1 (Depleted Uranium) Tank to M1A2**: The upgrade of an M1A1 Depleted Uranium (DU) armor tank to an M1A2 has a recurring WSUC of $2.9 million.

- **Upgrade of M1 105mm Tank to M1A2**: The upgrade of an M1 105mm tank to an M1A2 has a recurring WSUC of $3.9 million. There will be 210 M1 tanks upgraded to the M1A2 during Phase I of the upgrade program scheduled to be procured in the FY93-94 time frame with deliveries scheduled in FY95-96.

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[88]Thomas G. Zemke, Memorandum to the researcher from Program Executive Office, Armored Systems Modernization, U.S. Army Tank-Automotive Command, 19 February 1993, p. 1.

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