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A PRELIMINARY SYSTEM BASELINE FOR
A U.S. ARMY LIGHT ARMORED ASSAULT VEHICLE

by

Robert Mark Brown

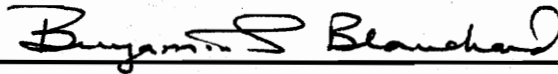
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degree of

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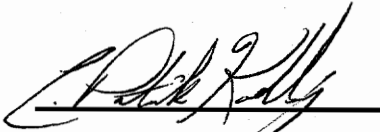
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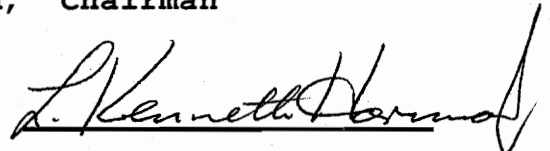
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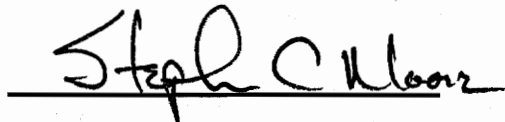
APPROVED:



Benjamin S. Blanchard, Chairman


Patrick Koelling


Ken Harmon


Stephen C. Moore

December, 1989

Blacksburg, Virginia

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A LIGHT ARMORED ASSAULT VEHICLE

by

Robert Mark Brown

Committee Chairman: Benjamin S. Blanchard

College of Engineering

(ABSTRACT)

The current mission of the U.S. Army requires the rapid world-wide deployment of troops to scenarios of critical interest to the United States within short notice. Currently, the only troops that can meet this deployment criteria are categorized as light and special operations forces. These forces do not have Armor or Armored Cavalry support because current U.S. Army Armor systems are not transportable within the deployment criteria, neither strategically nor tactically. Armor support traditionally provides combat endurance as well as increased mobility, lethal firepower, and shock effect to the enemy in a manner not attainable by dismounted troops alone. Therefore, the light forces of the U.S. Army are missing a key ingredient to land combat success and have a requirement for a system to provide this capability.

A Light Armored Assault Vehicle (LAAV) would meet this requirement. The objective of this project and report is to conduct a feasibility analysis and to establish a preliminary system baseline for a LAAV. The LAAV is designed through the system engineering process to have the necessary operational characteristics and transportability to provide the missing key combat capability. The LAAV would use current, low development risk

technologies.

This project and report presents a preliminary system baseline that investigates the performance trade-offs, schedule, potential cost, and recommended configuration for the LAAV system.

ACKNOWLEDGEMENTS

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1.0 Requirement for a Light Armored Assault Vehicle.

The idea for investigating the feasibility of a light armored vehicle started with a briefing from Major General Tait, then the U.S. Army Chief of Armor Branch and Commander of the Armor Center and Ft. Knox, concerning the status of the Branch. In his talk he outlined the role armor plays in the Army today and what the future holds for the Branch. What he said was not encouraging. Armor Branch, while still wielding tremendous influence on Army decisions and policy today, perhaps second only to Infantry Branch in influence, is rapidly losing its place in the Army structure. In 1977 the Armor Branch was the third largest branch of the Army behind Infantry and Artillery. Today, it is seventh in size and is even smaller than several combat support branches.¹ It will likely get smaller when the new generation of armored vehicles, known as Heavy Force Modernization, is fielded in the late 1990's. This is because the tank crew size is expected to decrease from four to three. This decrease is homage to technology and the increased weight required for heavy protection.

The culprit in the shrinkage of the Branch is that Armor Branch is rapidly losing its mission as the focus of world conflict moves from the cold war, and a possible engagement with the Soviet Union in Europe, to conflicts in the third world. This trend started with Korea, continued with Viet Nam, and is accelerating with the current atmosphere of "Perestroika" and "Glasnost" behind the "Iron Curtain."

¹Major General Thomas Tait, Address to the annual Armor Conference, Ft.Knox, Kentucky, March 1986.

Armor Branch of the U.S. Army failed to recognize a fundamental shift in the world situation and a corresponding shift in U.S. interests and policies. The Army, however, did not miss this shift and reorganized in the early 1980s. The Army restructured, placing almost half of its structure into the light forces category to enhance strategic flexibility. The Army's current armor equipment, the M60 series and M1 series tanks, as excellent as they are for a European battlefield, could not participate in this fundamental shift due to an inherent lack of strategic and tactical transportability. Thus, this lack of transportability is a major reason for the decline in the importance of the branch in influence.

Still, the reasons for having mounted armored combatants has not waned. The battlefield, through the principles of war, still demands mobility, mass, maneuver, surprise, and lethal firepower. There is still no better way to provide this than through armor or armored cavalry. Nowhere in the study of the art and science of warfare will one find stated that armor and armored cavalry have to be large, impenetrable, gun platforms. The fact that the U.S. Army light forces are lacking armor or armored cavalry capability is why the study of the feasibility of a LAV is so important.

Though the need to refocus the Armor Branch seems evident, the birth of combat systems is often not fully related to an established need or requirement. Advocacy for the system must be built in many places and this advocacy building is often a long, laborious, and painful process. It generally does not happen overnight. Some of the key power brokers that must be brought to consensus, in no particular order, are: the Armor Branch leadership, the Army leadership, the Department of Defense leadership, the Executive

Branch of the Government, the Congress, and the Defense Industry.² Any one of those power brokers is capable of stopping the development of a system if advocacy in that group is not well developed. The stoppage of a concept or a program is usually accomplished through the budget process because there are only so many ways a fixed budget can be divided up and distributed to satisfy infinite demands. There are other ways to stop a concept though, and among them are: the testing process, the technology development and insertion process, a catastrophe like the Challenger Space Shuttle, and probably many more.

The approach used in this study was to define the requirement and to use the systems engineering process to establish the basic performance specification for the LAAV. Then, investigation of technologies was conducted to satisfy the major system functions through the trade-off process. This investigation included the study of "off-the-shelf" systems to meet the need either "as is" or with modification. This investigation included full operational systems and components of complete systems. Next, the program was defined by establishing a preliminary schedule, life-cycle cost estimate, and a work breakdown structure. Thus, this report in its entirety establishes a preliminary system baseline.

Assuming advocacy could be built and the time, funds, and talents were made available, this project and report could be implemented. If this report were to be implemented, each subpart of the report

² Major David Gillman, U.S.A.F., instructor in Acquisition Policy, from a class discussion on the "Tortured Triangle" concerning Acquisition Policy and building program advocacy, Defense Systems Management College, Fort Belvoir, Va., April 1989.

would have to be broken down into its pure form and expanded in detail. This work would require many talented people and would take considerable time. The quantities of people required would include the research, development, and acquisition assets of the Army technological base, certainly in the hundreds. The time required will be defined by the program schedule. Much more detailed analysis would be required. Specific data would be required to do the detailed analysis required by both policy and statute. Much of this data is unavailable. Specifically, contractors were not always willing to commit to specific performance data for comparative purposes and much of the data were classified, such as lethality and survivability data of guns and armor respectively. The data would have to be located, developed, or cleared for use. This project and report would only constitute a start point for the program. The primary reason for the nature of this large effort would be the great expense from the U.S. Treasury and the critical nature of the need. The country could not afford to have this effort bungled either from a cost or consequence standpoint.

The system program will be known as the Light Armored Assault Vehicle, or LAAV. The system will have the the mission role of providing armored vehicle assault and defense support to the light, airborne, air assault and special operations forces of the U.S. Army. As such, it must provide the lethality, mobility and survivability inherent to the normal heavy armor tank, yet must allow for the transportability constraints imposed on the forces that it will support. Specifically, the system must be able to destroy enemy armored vehicles, be air droppable or air insertable, and must provide the crew with the armored vehicle protection

expected of a tank.

The system program will be categorized as a major program as the unit cost is expected to exceed \$1,000,000.00 per vehicle, which will comprise the ceiling unit design to cost goal. There will be enough purchased systems to equip the light divisions at a level of one battalion (58 LAAVs) per light, airborne, and air assault brigade.³ There are six such divisions in the current force structure of the U.S. Army and each division has up to four brigades. Each brigade has up to four battalions of light, airborne, or air assault infantry. Each battalion has up to six companies. Additionally, one LAAV company (14 LAAVs) will be assigned to the Special Operations Command which is comprised of the U.S. Army special forces units and Ranger Battalions, as well as other units.

1.1 Need/Threat.

The U.S. Army currently has an equipment capability deficiency in that the current structure of the Army's airborne, air assault, light, and special operations forces have no armor support capability. This is a critical capability that the Army must obtain due to the nature of its worldwide mission. Figure 1 shows that the most high risk scenario for the United States would be to engage in a land war in Europe or the Middle East, yet it is the least likely

³ This structure is merely a proposal from which to establish a system baseline. Study would likely indicate a different structure is optimal. Establishing the correct structure is not the intent of and is beyond the confines of this study.

U.S. ARMY OPERATIONS

INTENSITY VS LIKELIHOOD

RISK SCENARIO

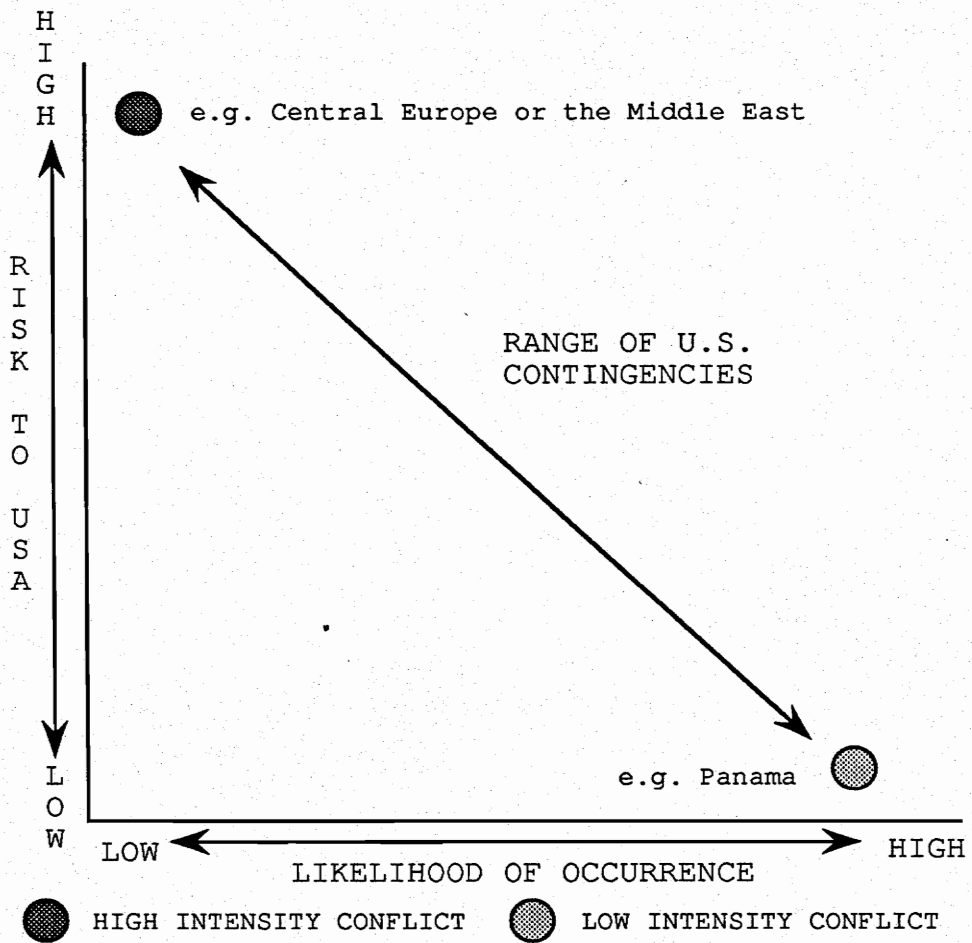


FIGURE 1

scenario.⁴ At the same time, figure 1 shows that a lower risk scenario to the United States would be to engage in a low intensity conflict such as in Panama, Nicaragua, or Colombia; yet the likelihood is far greater. It is precisely in the latter scenario that the U.S. Army has a glaring weakness in capability. As determined by U.S. foreign policy and intelligence information, likely enemies of the U.S., even in Third World countries, have significant armored vehicle capabilities. For example, the Soviets have had the BMD airborne armored vehicle for many years. Nicaragua has one known T-55 tank battalion, as well as other lighter armored units. Libya, Iran and Cuba have considerable armored forces. Figure 2 shows that the structure of the U.S. Army is designed to retain the flexibility required to respond to situations either in the high to mid-intensity conflict, for example Europe or the Middle East; or the low intensity conflict, such as Panama. The mission of responding to the low intensity conflict falls to our light, airborne, air assault, or special operations forces. These U.S. forces, the same forces that have the previously mentioned capability deficiency, must respond to world wide crises within hours notice. Generally, their mission is to seize and hold key terrain assets such as bridges, ports, or airfields and retain them for a specified time. They are expected to retain this terrain until they can be relieved by forces of more staying power or capability but are much less responsive due to transportability demands. Since the lighter forces are limited by what they can drop in or carry with them, their sustaining power is very limited. The

⁴ The concept for this figure was taken from an address to the Combined Arms Staff and Services School of the Command and General Staff College by then Chief of Staff of the Army, General John Wickham in November 1985. It is my understanding that this figure concept was widely presented throughout the Army, DOD, and the world.

U.S. ARMY FORCE STRUCTURE

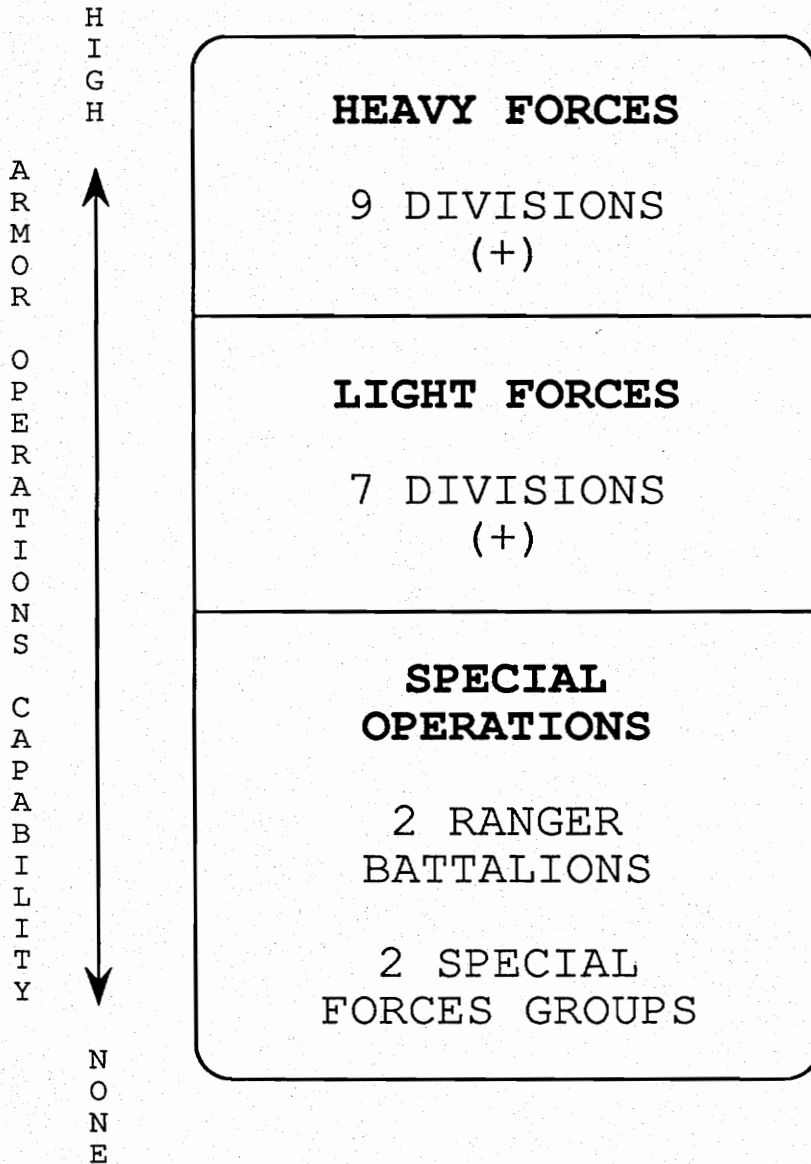


FIGURE 2

situation is further complicated by the fact that hand held anti-armor weapons, carried by these forces to provide anti-armor capability, are rapidly losing effectiveness to armored vehicles. This is due to technological advances in armor design and materials such as reactive and laminated armors. Currently, potential adversaries of our rapid response forces have the ability to rapidly counter-attack our dropped-in or inserted forces with armor, thereby providing a capability mismatch. Our forces would be hard pressed to survive in such scenarios and to successfully execute their mission. Currently, the threat has not been advancing specifically in the area of creating an armor-light forces mismatch, as they recognize they have a significant advantage. They recognize there is no need to commit assets to maintain this advantage in light of our inaction. Still, the threat assets being committed to improve their regular armored forces also may be viewed as aggravating the described situation, as the improved regular armor forces may also be used against our rapid deployment forces. The expected threat response would be to commit scarce resources to maintaining their edge in this area, thereby slowing their capability to apply unrestricted improvements to their conventional armored forces. The threat would be at a disadvantage in that they would be playing catch up in the development cycle if we were to develop and field a new generation and high technology LAAV.

1.2 Required Initial Operational Capability (IOC).

The required IOC is the present time. However, it is recognized that proper research and development is required to develop a new system or to develop and/or test an "off-the-shelf" solution or any

modifications to an "off-the-shelf" solution, of which there are several possibilities. Therefore, six years is allotted to the system program to provide for this work.⁵ The initial operational capability will be defined as the first operationally fielded and trained LAAV battalion which must be in place by the end of 1996 (FY1997).

1.3 Operational and Organizational Plan.

The LAAV will be employed by inserting all or portions of the LAAV unit in advance of, with, or shortly after the employment of the light, airborne, air assault or special operations forces. Employment decisions will be made by the operational commander as the situation requires. Doctrine on employing and fighting the LAAV unit will be developed and refined by the appropriate U.S. Army Training and Doctrine Command (TRADOC) organizations. The U.S. Army Armor School will take the lead and will be supported by the Airborne and Special Operations Board.

As previously stated each brigade of light infantry, airborne infantry, air assault infantry and the Special Operations Command will be equipped with the LAAV. The Operational Mode Summary of the LAAV is defined as; the LAAV will have to operate in a mission environment, including possible hostile enemy engagement, 24 hours per day for a 72 hour operation. Since fuel and ammunition resupply will be a limiting operational factor, refueling and resupply operations will not normally occur during the 72 hour scenario.

⁵ This figure is chosen to establish a system baseline and may not be optimal given further study.

Therefore, the LAAV must carry enough of each, an unspecified amount, to meet the operations mode of the 72 hour scenario without resupply from outside sources.

1.4 Operational Characteristics.⁶

Operational range will be limited due to the nature of the mission and will be no more than 100 miles in the 72 hour scenario and/or consumption of one tank of fuel. Weight must be limited to 23.45 tons or less due to the transportability requirements.⁷ It is required that the LAAV have a design envelope of not more than 100 inches width, 102 inches height, and 480 inches in length. The weight must not exceed a hard ceiling of 46,900 pounds with concentrated load not exceeding 50 psi. This performance envelope is outlined by the capabilities of the U.S. Air Force C-130 transport aircraft. The desired design envelope is that the LAAV must not exceed 72 inches in height, 80 inches in width, and 360 inches in length. The desired weight must not exceed a hard ceiling of 22,900 pounds, which is what the CH47D helicopter can transport at 2000 feet altitude for 30 nautical miles on a 70 degree Fahrenheit day. One LAAV must have the capability of defeating a threat tank platoon (three tanks) within 10 seconds. The vehicle crew must survive up to 75mm Rocket Propelled Grenade (RPG) chemical energy anti-tank missiles or 75mm kinetic energy projectiles.

⁶ The operational characteristics for the LAAV were chosen to provide a framework for establishing a system baseline. However, they were selected to realistically support, as closely as possible, the mission of the light forces as known by the author.

⁷ All transportability specifications were drawn from the same source. Joseph F. Cassidy, Transportability for Better Strategic Mobility. MTMC Pamphlet 70-1, Newport News, Va., June 1985, pp.15 through 32.

Reliability, Availability and Maintainability (RAM) requirements must support the 72 hour operational scenario. The LAAV must be able to acquire and engage targets under conditions of darkness, smoke, haze, fog, wind, rain, dust, etc. An additional goal will be to maximize standardization and interoperability with NATO and other allied countries; particularly with regards to fuel, ammunition, communications, power, and transportability. Where possible, technologies and design will be used to maximize capability but minimize size, weight, and logistical demands. The LAAV must have inter- and intra-vehicle communications systems compatible with the standard Army communication system, Single Channel Ground and Airborne Radio System (SINGARS). Crew access and egress to the system must be able to be secured from inside the system. The LAAV must be hardened against electromagnetic pulse and directed energy weapons. The system should display graceful, not catastrophic, degradation during combat operations. All other requirements of the system such as camouflage, test measurement and diagnostic equipment, and any others not mentioned must cooperate with standard Army and/or NATO equipment or procedures. Individual items in question will be addressed on a case by case basis and will be added to this requirement via an update or revision.

1.5 Technical Assessment.

Non-Developmental Items (NDI), commercially developed systems that can be bought "off the shelf" with little or no modification, will be investigated. There are at least three known candidates. NDI systems will be investigated through market surveys. An assessment of the amount of development required to integrate the NDI system

into standard Army operations and procedures will be determined. The NDI approach is viewed to be a low risk technical solution as well as highly desirable with regard to schedule.

1.6 System Support Plan.

This plan will be discussed in detail later in the system baseline. Briefly, the system support plan must work in concert with standard Army maintenance practices and will be a three level concept.

1.7 Human Factors Assessment.

This system will require new manpower demands. The extent of the demands are not known at this time. These demands should be minimized by design and will be investigated in the trade-off process. Additionally, since this is a new system, the personnel system will have to create at least two new training specialties. The first new specialty will be the operator(s) and the second will be the maintenance personnel. It is desired that the existing armor skills and armor maintenance personnel can learn the new skills with additional training rather than creating totally new skills. No special aptitudes should be required of either operator(s) or maintenance personnel. Human Factors Engineering must insure that the man-machine interface reacts synergistically to minimize system demands such as manpower, personnel, maintenance, safety hazards, and health hazards for any reason.

1.8 Standardization and Interoperability.

The LAAV must be interoperable with all other U.S. Army and to the maximum extent possible, NATO equipment. This is particularly important for communications, petroleum products, ammunition, and transportability assets.

A life-cycle cost (LCC) assessment will be conducted on candidate systems for trade-off purposes and will be included later in this baseline.

A proposed program schedule will be included later in this baseline and will be compatible with the six year development requirement stated earlier in this requirement.

Other items will be included in the baseline to include: Functional Analysis, Functional Allocation, Work Breakdown Structure, Requirements Allocation, and Trade-Off Analysis between alternative concepts.

2.0 LAAV Functional Analysis.

The LAAVs functional analysis is based on the LAAVs operational requirements and the maintenance concept which will be discussed in a later paragraph.

2.1 Mission Scenarios.

There are several possible mission scenarios for the LAAV and they are:

- 2.1.1 Load for transport.
- 2.1.2 Insert into tactical scenario.
- 2.1.3 Move to and between operations.
- 2.1.4 Defend against attack.
- 2.1.5 Attack hostile equipment and positions.
- 2.1.6 Rearm and refuel.

2.2 Operational Mission Profile.

It must be kept in mind that the operational mission profile of the LAAV would not normally exceed 72 hours without outside assistance, because 72 hours would be the maximum engagement time of the light or special operations forces. Figure 3 represents a functional flow block diagram for the LAAV. Figure 3 is only intended to demonstrate how functional analysis would take place. Every top level function would be analyzed to the lowest possible level just as figure three shows function 5.0, Attack, and function 5.2, Lay Gun, being defined.

FUNCTIONAL FLOW BLOCK DIAGRAM

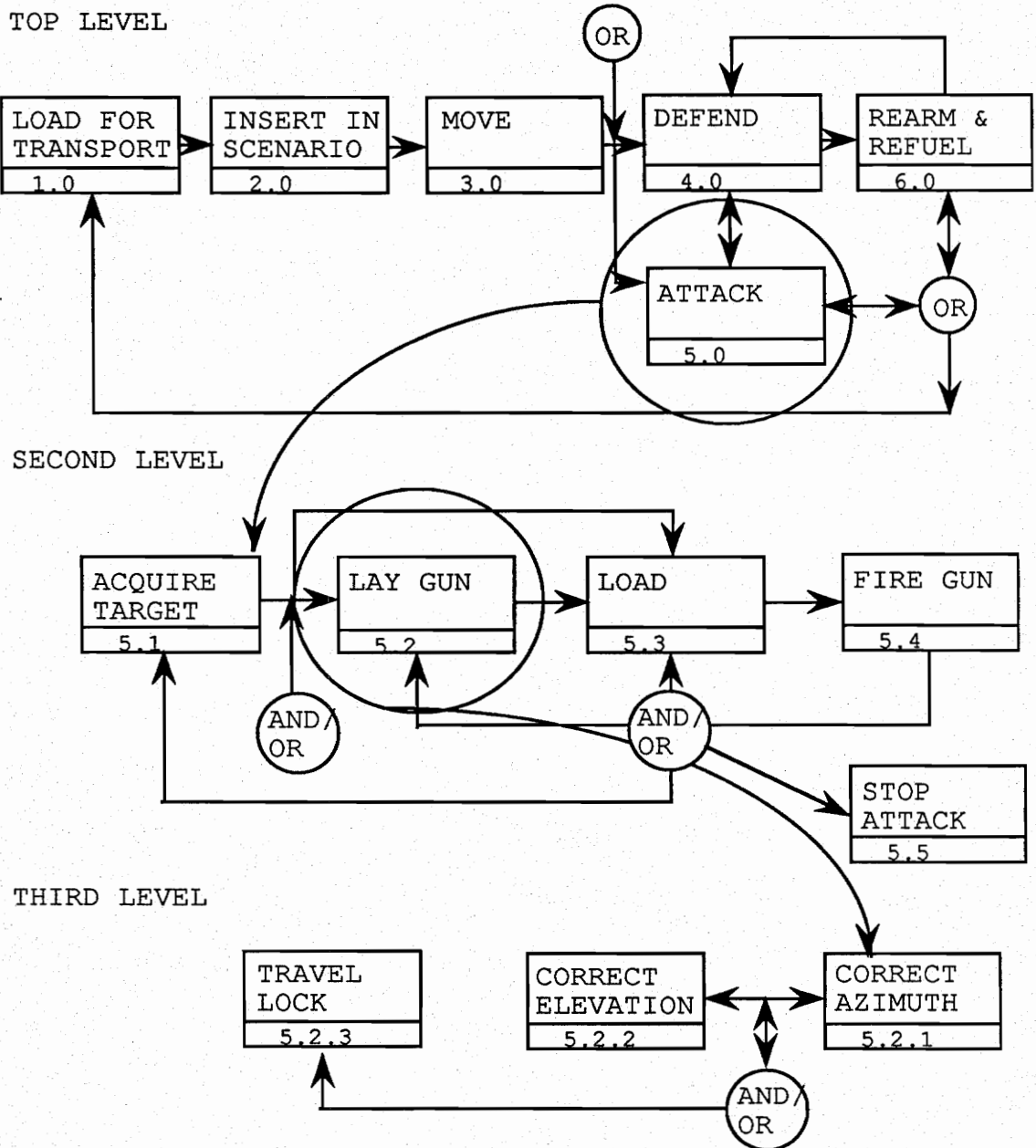


FIGURE 3

3.0 Functional Allocation.

The LAAV will be broken into subsystems and functions will be allocated to those subsystems. The LAAV system is broken down into the following major subsystems:

The armament system is the system that destroys enemy targets. It consists of all components that deliver destructive ordnance to a target and includes, at the lower levels, the gun or guns, fire control mechanism, loading mechanism, ammunition, and ammunition stowage system.

The propulsion system is the system that moves the LAAV. At the lower levels it would consist of an engine, transmission, final drive system, fuel system, and steering mechanism.

The communication system is the system that provides for communication of the system between the crew members on a single LAAV and between a LAAV and other LAAVs or organizations. At the lower system levels it would include an intercom, a radio receiver-transmitter, and battlefield management systems.

The survivability system is the system that provides crew protection and includes active and passive measures. At the lower system levels it would include armor, smoke generator/launcher, fire suppression systems, and Nuclear, Biological, Chemical (NBC) protective systems.

This system is the framework upon which all of the other systems

are built and/or to which they are attached. It would include the frame, wheels, suspension arms, and/or tracks.

The vehicle system and subsystem functional allocation diagrams are shown in figures 4 through 8.

LAAV FUNCTIONAL REQUIREMENTS & ALLOCATION (TOTAL SYSTEM)

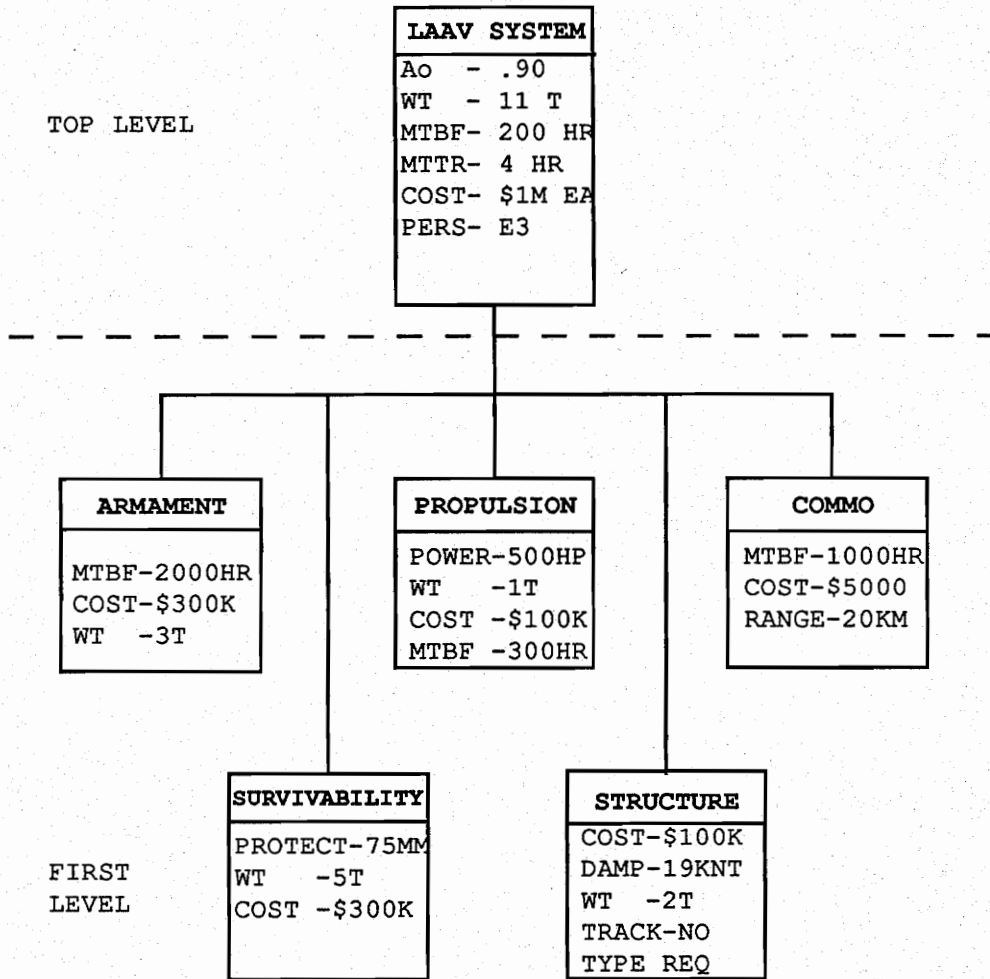


FIGURE 4

LAAV FUNCTIONAL REQUIREMENTS & ALLOCATION (ARMAMENT)

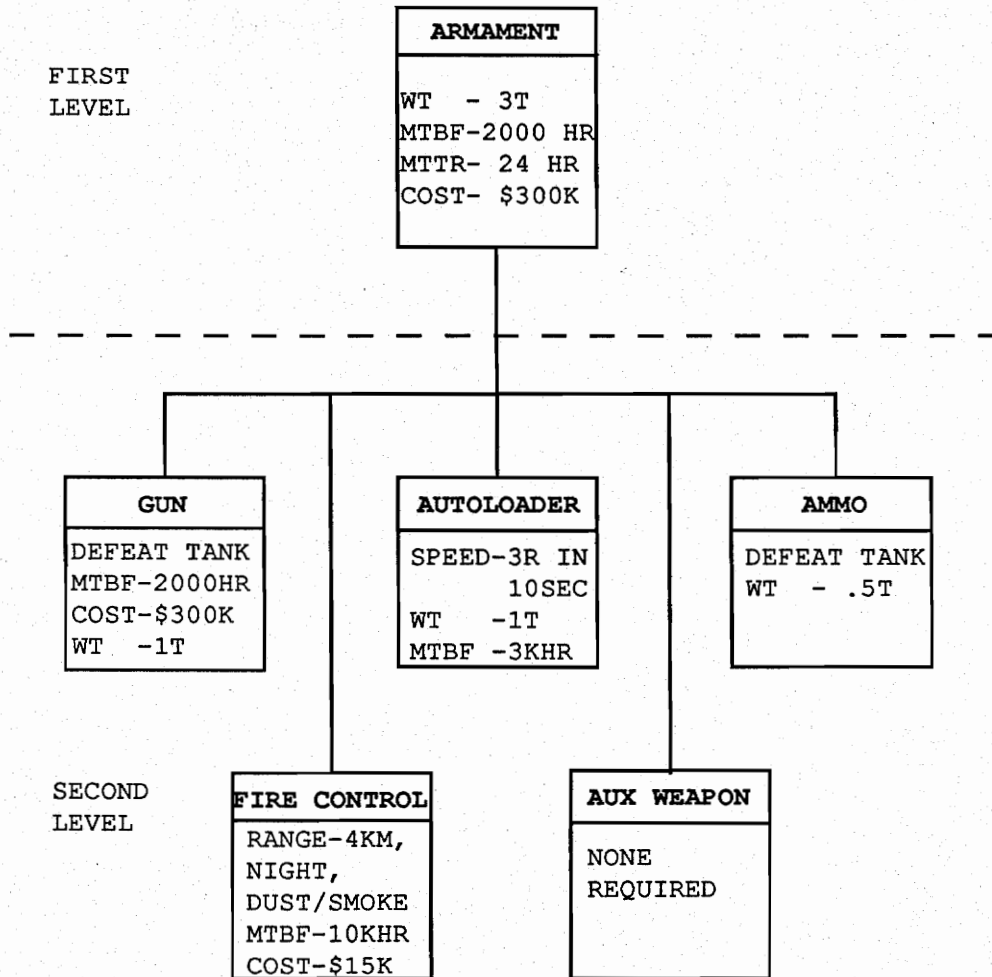


FIGURE 5

LAAV FUNCTIONAL REQUIREMENTS & ALLOCATION (PROPULSION)

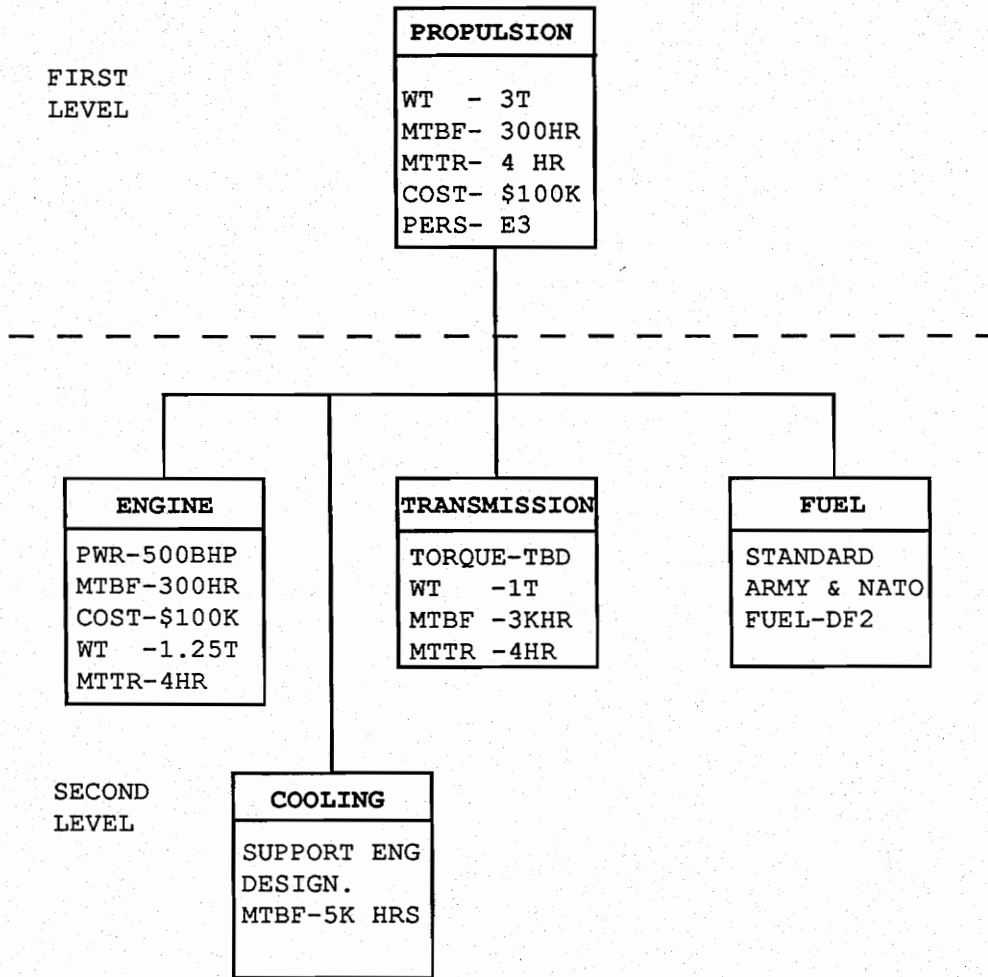


FIGURE 6

LAAV FUNCTIONAL REQUIREMENTS & ALLOCATION (COMMUNICATION)

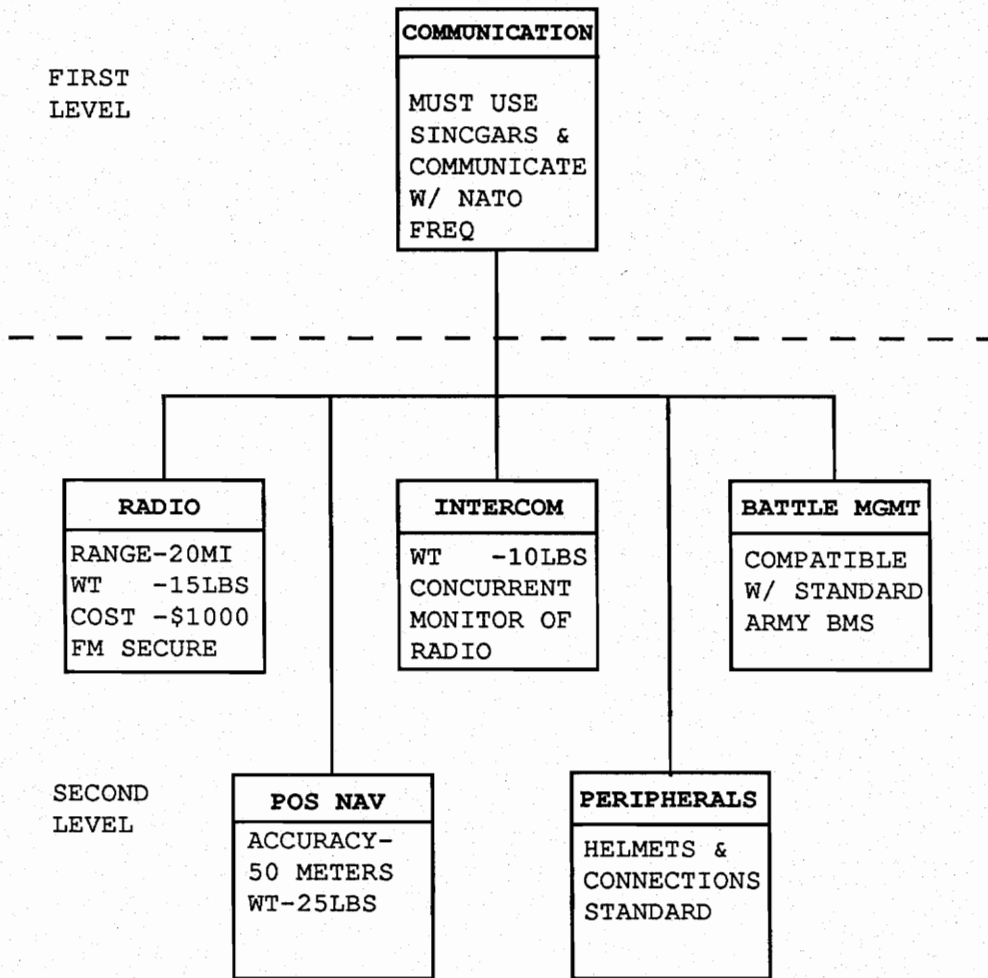


FIGURE 7

LAAV FUNCTIONAL REQUIREMENTS & ALLOCATION (SURVIVABILITY)

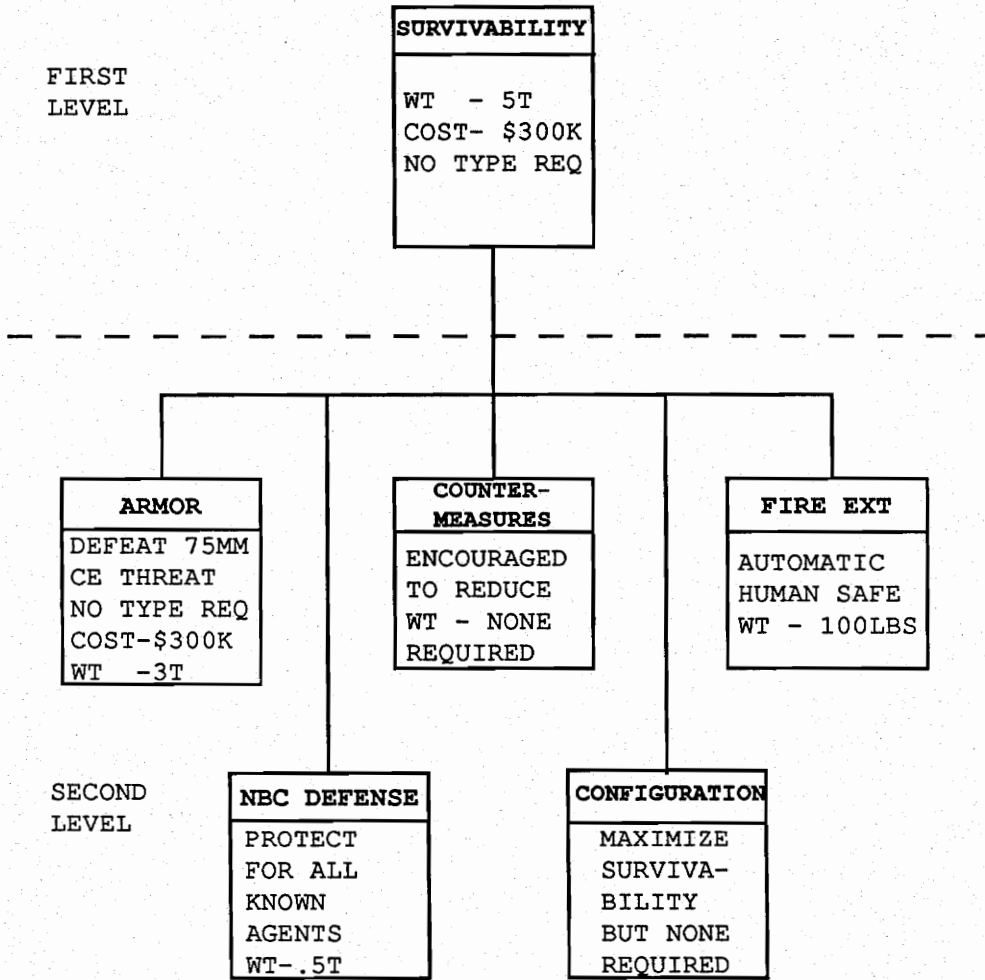


FIGURE 8

4.0 Maintenance Concept.

The LAAV maintenance concept will be a three level maintenance concept. There will be an operator or system level of maintenance, an intermediate or unit level of maintenance, and an assembly or depot level of maintenance. The maintenance concept is diagramed at figure 9.

4.1 System Level Maintenance.

The system level of maintenance will be extremely limited due to the operational mission scenario. It will consist primarily of the crew checking fluid levels and performing minor mechanical adjustments. System level maintenance will be conducted with a minimum number of tools; a maximum of ten is the desired number. Reliability of components will be designed so that the total system will have a reliability and operational availability that will exceed the 72 hour scenario.

4.2 Intermediate Maintenance.

Intermediate maintenance will also be limited due to the 72 hour scenario. System RAM (Reliability and Maintainability) parameters will be designed to exceed 72 hours due to the limited capability of the unit maintenance personnel to perform during this scenario. These personnel have limited capability due to limited supply and mechanical capabilities that result from the isolation imposed by the mission requirements. However, in training and non-combat situations, the unit maintenance personnel will have the capability to detect and isolate faults and to repair and replace most

LAAV MAINTENANCE CONCEPT

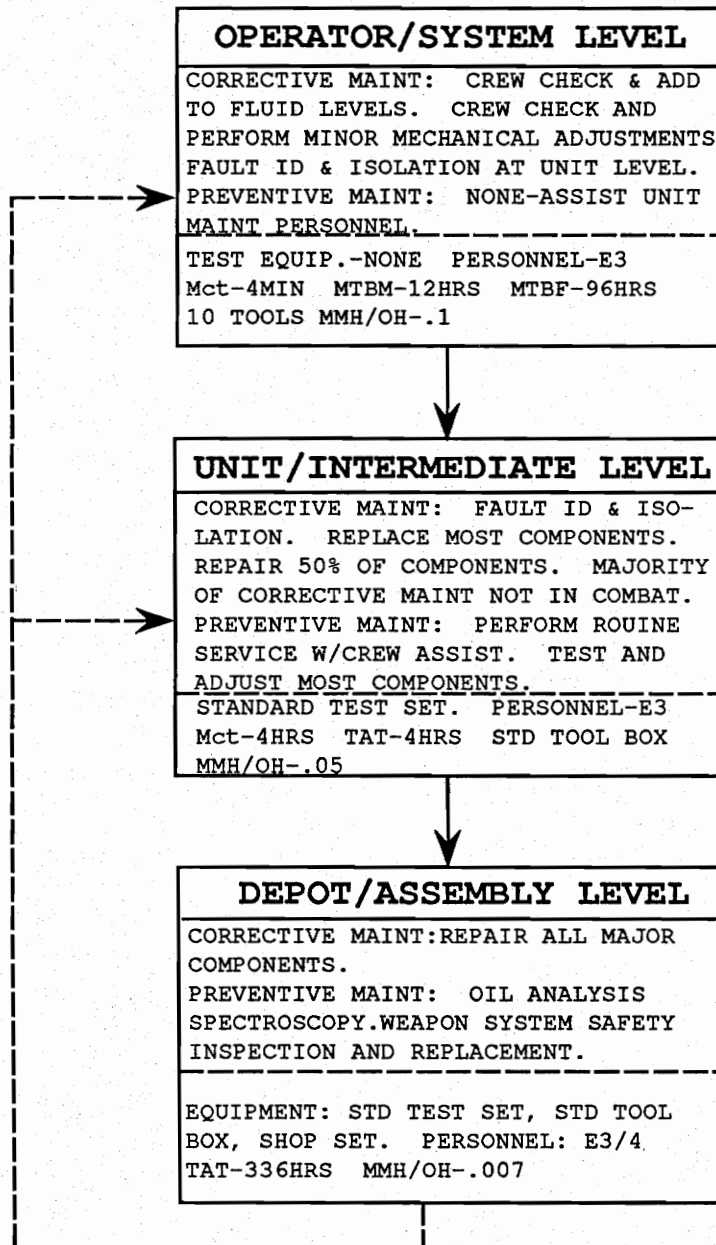


FIGURE 9

components. This later capability will include evacuation of replaced components to depot for repair.

4.3 Depot Maintenance.

Maintenance at this level will include repair of major components such as cannons, engines, fire control systems and transmissions, etc. This is the maintenance level that will require the most highly skilled and trained personnel and is where most of the heavy maintenance will occur. This activity will occur away from the battle area. During an operational mission, if failure of this type occurs, personnel and equipment necessary to effect repairs will be inserted or extracted by unit aviation assets such as the UH60 or CH47D helicopters.

5.0 LAAV System Life-Cycle.

It is difficult to determine the exact system life-cycle for the LAAV. For example, the LAAV will replace the M551 Sheridan Armored Assault Vehicle. The Sheridan is in service with the 82nd Airborne Division today and was first fielded early during the Viet Nam War. Clearly, when considering the movement of doctrine and technologies, the M551 was not expected to have a life-cycle as long as it has had. However, planning must take place and there will be a defined system life-cycle. The life-cycle will be diagramed in figures 10 and 10A. The basic components of the system life-cycle will be discussed in the following paragraphs.

5.1 Requirements Definition.

This phase has already been completed and a written requirement is found in paragraph 1 of this baseline.

5.2 Conceptual Design and Advanced Planning.

This baseline is the actual start point of the conceptual design and advanced planning. Major subsystems will be evaluated for alternative solutions and trade-offs. Additionally, "off the shelf" solutions will be examined to determine if they can effectively and economically satisfy the requirement. A system concept is the final output of this stage of the design. This phase has one year allocated for completion.

LAAV SYSTEM LIFE CYCLE

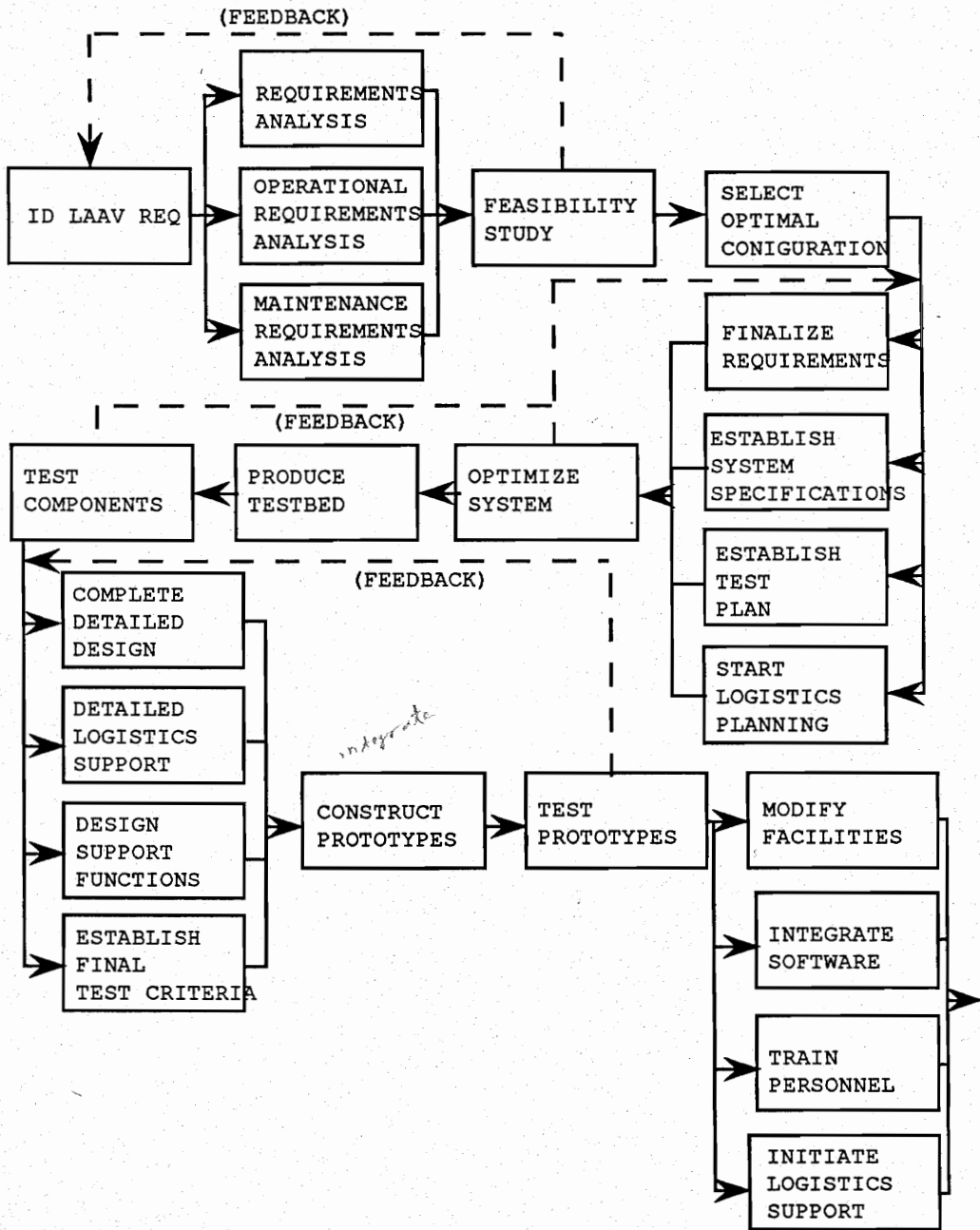


FIGURE 10

LAAV SYSTEM LIFE CYCLE (CONTINUED)

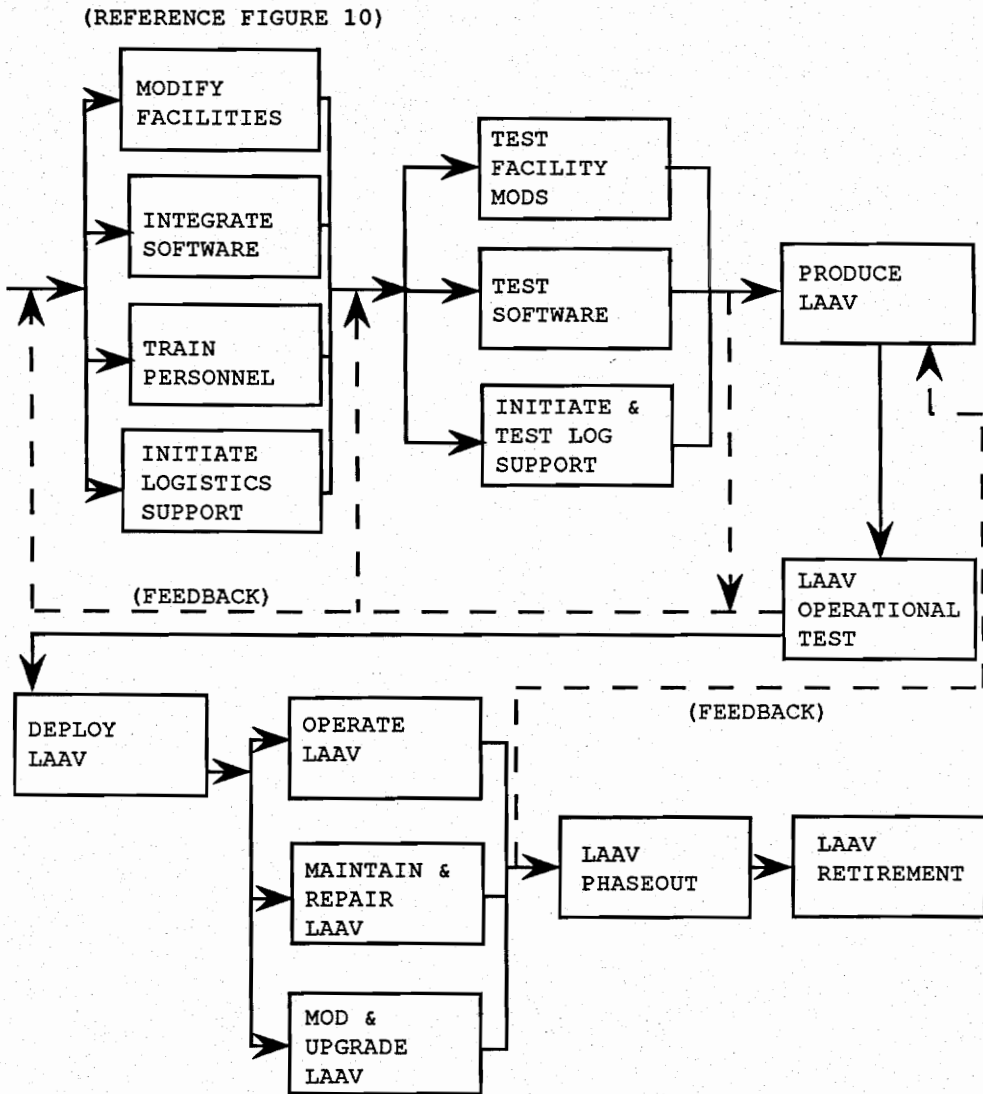


FIGURE 10A

5.3 Preliminary System Design.

During this phase, the requirement would be finalized and scrubbed. The LAAV system specification will be established as well as the initial test plan. Finally, this phase is the start of logistical concept planning. This phase also has one year allocated for completion.

5.4 Detailed System Design.

During this phase, detailed design and detailed logistical planning occurs. Support is designed and is finalized. The main activity during this phase is the construction and testing of prototypes. This phase has two years allocated for completion.

5.5 Production.

During this phase the construction of facilities is completed. Further, personnel are trained and system logistical support is initiated. Finally, and most importantly, the LAAV is built and fielded. This phase also has two years allocated for completion and this phase will conclude the allotted six year development cycle.

5.6 Operations and Support.

During this phase, the system is in the field in full force meeting the need. The length of this phase is the most difficult to determine as it depends on the march of technology, the threat, the budget, and a host of other influencing factors. The planning

factor for the LAAV will be twenty (20) years; keeping in mind that the M551 has already exceeded that figure.

5.7 Phase out and Retirement.

During this phase, the system will lose its mission and will undergo reduced support and/or displacement by new equipment. Accordingly, it will be disposed of either by demilitarization, scrapping, or by retrofit and rebuild for sale to foreign nations. This phase will be accomplished over several years coinciding with the production and fielding of a replacement system and will therefore likely last from at least two to four years.

6.0 Trade-Off Analysis.

The LAAV system will have trade-off analysis done in several areas. These areas are: propulsion (which is further divided into power and transmission), armament, and survivability (which includes configuration between armor, crew, and components). The driving factor in this trade-off analysis is the acceptable balance between mobility (to include transportability), lethality, and crew survivability. The three selected trade-off areas are the primary factors that affect the trade-off balance. Many times the lines of distinction between the three will not be clear. For example, a smaller and more lightly armored vehicle may be just as survivable as a larger more heavily armored vehicle.⁸ This situation results from the fact that the light vehicle presents itself as a smaller and faster, albeit easier to penetrate if hit, armored target. Trade-offs such as this abound for every subsystem.

6.1 Propulsion System.

The propulsion system consists primarily of the power plant and the transmission. There are three major possible solutions for the power plant and two major possible solutions for the transmission.

Power Plant. Given current technologies, the three possible solutions to the power plant requirement are: the gas turbine engine, the diesel engine, and the rotary or wankel engine. There are other engine possibilities, the Stirling Engine for example, but

⁸ Mark Reches and Benson King, "U.S. Army Survivability Information Resource," Army R.D. & A. Bulletin, November-December 1989, pp. 33 through 35.

at this point they are not developed enough nor are there enough regular producers for them to be seriously considered. The major trade-off areas for engines are: power, weight, volume, and fuel efficiency. These areas are critical if the LAAV is to remain small enough to move with and support the light and special operations forces. Since the requirement for the LAAV does not call for long range, fast speed, or fuel efficiency, the trade-off areas are prioritized in the following order: weight, volume, power, and fuel efficiency. The three possible solutions are the diesel engine, the gas turbine engine, and the wankel engine. Each has its own particularly desirable attributes. The attributes are arrayed in table 1.⁹

TABLE 1 ENGINE ATTRIBUTES

	Weight (pounds)	Horsepower (BHP)	Volume (cubic feet)	Fuel Consumption (lbs/hph)
Wankel	1420	750	29.8	.411@3400rpm
Diesel(1)	2650	600	75.25	.360@2600rpm(max.)
Diesel(2)	2500	736	52.3	.375@2300rpm(max.)
Gas Turbine	n/a*	1070	118.4	.42@ max. BHP

*in development

The best available data on the gas turbine indicates that the weight will be less than the diesel's but greater than the wankel. Since

⁹ The data in this table were taken from numerous items of printed advertising material from commercial engine producers. Notable companies included Detroit Diesel, Cummins, Hercules, John Deere, General Electric, Caterpillar, and TEXTRON Lycoming.

the gas turbine is still in development and will not be available, even if still on schedule, until the mid 1990's (based on its current schedule) the clear winner in the propulsion trade-off is the wankel. The reasons are that it is the lightest and smallest engine by far, yet delivers more horsepower than any engine except the developmental gas turbine. Additionally, it compares favorably with all engines in fuel efficiency at maximum Brake Horsepower (BHP). The small volume and weight will also contribute to less required armor and therefore further lighten the weight of the LAAV. Finally, it is "available off the shelf" now and requires only system integration and no further development. Even if the gas turbine were lighter than the wankel, the volume is almost four times as large, contributing to a much greater vehicle weight. The gas turbines' higher horsepower does not offset this disadvantage even if it were not still in development. The cost factor for each of these power subsystems was virtually equal from the available data.

Transmission. There are two possible solutions to the transmission requirement and these solutions are the mechanical drive and the electric drive. Performance data for the electric drive are difficult to obtain since almost all current armored vehicles use mechanical drive. However, it is not an exotic technology.¹⁰ It is in use today in railroad locomotives and ships. Additionally, the Belgians have demonstrated an 8 ton armored vehicle with electric drive. The electric drive significantly reduces weight while allowing for maximum configuration flexibility.

¹⁰ Michael R. Green, "Electric Drive Could Mean Smaller, Lighter Tanks.", Armed Forces Journal International, October 1989, p.98.

Since weight is the critical design driver in this system and mechanical drive systems are heavy and must be coupled to the power plant, an unscientific selection of electric drive will be made for the LAAV. Although data was difficult to obtain, for purposes of comparison, a heavy infantry fighting vehicle (that would carry an infantry squad into battle in the high intensity conflict) armored with steel armor, would weigh between 57.2 and 56.4 tons if equipped with a mechanical transmission. The same vehicle, if equipped with electric drive, would weigh about 50.1 tons (an 11 to 12.5% weight savings). Parametrically, similar weight savings are attainable on lighter vehicles. Other benefits include greater RAM, fuel efficiency and greater horsepower to weight ratios. Therefore greater tractive power and speed are possible.

6.2 Armament System.

The armament system consists of the fire control mechanism, the gun or missile, and possibly the auto loader. The armament must always have fire control, usually consisting of range finder, sights, traversing and elevating servomechanisms, and a conventional or unconventional (low or no volume) turret. Current fire control systems are highly developed and use laser or radar range finders as well as highly developed electronic and/or hydraulic servos. Since the current systems are so good, it is envisioned that the current Bradley Fighting Vehicle Integrated Sight Unit (ISU) or similar system will be used for fire control. It is lightweight, compact, in production, relatively inexpensive, and meets all performance requirements. The government owns the technical data package and must only accomplish integration engineering to adapt this or a

similar system to the LAAV. The real trade-off analysis comes in determining to use an auto loader or a crewman, in deciding which system to use for delivering ordnance, and in deciding which type of turret to select (the last will be done in the survivability/configuration trade-off).

Loading Mechanism. There are two possible solutions to the loading mechanism problem. The first is to use a crewman and the second is to use an auto loader. Each has significant advantages and disadvantages.

Crewman. A crewman is not as consistent as an auto loader. Additionally, a crewman is prone to injury. Finally, a crewman requires a small additional amount of increased space under armor over an auto loader. Over the life-cycle the crewman is more expensive due to training, pay, and benefits considerations. However, a crewman is lighter, can load faster in spurts, and can perform mandatory crew duties such as vehicle maintenance, security, and communications.

Auto Loader. An auto loader is more consistent than a crewman, but can break down. The advantage of compactness is offset by the fact that it is heavier and is slower in emergency situations. It also cannot perform vital crew duties such as security and operator/crew maintenance. After procurement costs, the auto loader's life-cycle costs are much lower.

Trade-Off Analysis. Since the operational mission scenario is limited to 72 hours, the crew duties argument is mitigated. Human

factors studies have shown that the human can operate in a combat effective manner for up to 72 hours in a reduced sleep, high stress scenario. Beyond that, human effectiveness is significantly reduced. The compactness of the auto loader and the lighter weight of the crewman is about an equal trade-off. Therefore, the real trade-off consists of determining if the spurt capability of the crewman is worth the additional life-cycle cost that having a crewman imposes on the system. This can only be a subjective evaluation. Since the mission of the LAAV is to provide emergency, but not perfect, armor/anti-armor support and the current budget situation is difficult at best, the auto loader is selected for the LAAV.

Weapon System. There are numerous choices that can be made for weapons. The system can have a gun from 25mm caliber to 120mm. The latter will defeat almost all current armored vehicles today but obviously imposes size, weight, and recoil costs. The former will defeat most lightly armored targets at a minimum size and weight, but generally cannot defeat tanks of most types. The 50mm, 75mm, 90mm and 105mm guns offer intermediate solutions, with intermediate results.

Missiles can be used and are highly effective in defensive roles. There are two types of missiles: line of sight anti-tank and non line of sight or top attack missiles. The latter can attack the lightly armored tops of armored vehicles. The drawbacks to these systems are that they must be visually tracked to the target, they use chemical energy which is susceptible to defeat by reactive armors, they are not the most effective in an attack role as they

must be fired from stationary positions, and most have long times of flight to the target. The final possible solution is electromagnetic/electrothermal (EM/ET) launch gun technologies. These are promising but are still developmental and currently pose serious electric power consumption, storage, and regeneration problems.¹¹ Because of the problems and disadvantages mentioned with the missiles and EM/ET technologies this trade-off will only be conducted on direct fire guns of varying sizes.

Background. Most modern tanks fielded in the world today can be defeated by the 90mm and 105mm guns, at least in the top, flank, or rear of the tank. The most modern tanks fielded by NATO and Warsaw Pact countries, and deployed in several third world countries can only be frontally defeated by the 120mm or larger gun. Generally, the most modern tanks would not be encountered in areas considered to be possible low intensity conflict areas. However, other, less modern tanks, would be expected. The trade-off lies in how much size and weight it is possible to accept to gain the maximum lethality for the weapon while not imposing unacceptable weight gains. It must be remembered that this problem has synergistic ramifications. Not only does the weapon get larger and heavier, but so does the ammunition and the armor required to protect it in a conventional or unconventional turret. Also, as the ammunition gets larger and heavier, so must the auto loader and the space to store the ammunition. This generally results in fewer onboard rounds carried and this has significant operational capability and systems support impacts. Analysis must be conducted to determine an

¹¹ FMC Corporation, "Electromagnetic Gun Weapon System-A Systems Look.", a report prepared for Robert Moore, Defense Advanced Research Projects Agency, November 1987.

acceptable percentage of targets that can be defeated by the smallest weapon possible at a given range. Much of the data on lethality is classified. The confidence interval selected for defeating threat targets will be assumed to be .85 at 2000 meters for this project, or the gun must defeat 85% of all targets at 2000 meters that it will encounter in worldwide scenarios. Obviously, the gun will not defeat the most modern tanks with frontal shots, because the lethality requirements to do so and the transportability requirements for the operations mode are mutually exclusive.

Criteria. The rank ordered criteria for selecting the weapon will be weight, lethality, number of carried rounds, size, and power requirements. Lethality is composed of caliber, range, muzzle velocity, penetration power, etc. Since there are no data that will allow a comparison of the same performance characteristics, the systems will merely be rank ordered. Obviously a 105mm system is much more lethal than a 25mm system. However, it may or may not be acceptable in terms of size. Size, like lethality, will consist of a variety of factors and will be rank ordered. The size factors are length, width, and height. Table 2 arrays the weapons attributes.¹² In rank order comparisons, low numbers are better.

Trade-Off Analysis. Obviously, there are a wide variety of choices in terms of weapons and configurations. Notably, a conventional turret 105mm system comes in a 5.2 tons. This system is clearly the most lethal but also the largest. However, it would

¹² The data in this table were taken from numerous printed advertising materials from commercial contractors. Notable contractors in this group included Cadillac Gage TEXTRON, Teledyne Continental Motors, Delco Electronics, and McDonnell Douglas.

TABLE 2 WEAPON SYSTEM ATTRIBUTES

weapon	wt. (pounds)	lethality (rank)	# rnds	size (rank)	power requirements (horsepower)
25mm	244	5	n/a	1	1.5
30mm/40mm ^a	325	4	n/a	2	1.5
40mm/.50 cal [^]	2,050*	3	100/200	4	8.0
35mm/50mm ^a	475	2	n/a	3	3.0
105mm/.50 cal [^]	10,450*	1	8/400	5	n/a

*with conventional armored turret-all others gun only

^aone gun, two ammunition systems

[^]two gun systems

still only consume 45% of the desired vehicle maximum weight and only 22% of the required vehicle weight. Therefore it is a clearly feasible option from the weight and lethality standpoint. Further, it does not exceed size limitations imposed by transporting aircraft. Since the wankel engine was selected there is ample power available regardless of the operational requirements, even though they were not available. The only major concern with the 105mm/.50 cal system is the number of onboard rounds, particularly 105mm. This system carries 8 rounds. The requirement stated that the system must defeat a threat platoon within 10 seconds. A threat platoon consists of 3 tanks. 8 rounds times an .85 probability of kill at 2000 meters is equal to 6.8 kills, which exceeds the requirement of three kills (threat platoon). Therefore, 8 rounds is an adequate, if not optimal, onboard round capacity. If the number of rounds remained a concern, additional weight reduction measures

are available, since this is a conventional turret with a crewman loader. Use of the previously selected auto loader and a low volume configuration would have substantial weight savings estimated to be at least 25%. Additional rounds could be added with this weight savings. The next consideration would be if the 120mm would be feasible. From a weight standpoint it probably would be, at least in a low or no volume turret configuration. However, the number of on board rounds would decrease to the point where meeting the kill requirement would be doubtful. The 120mm could probably only carry 4-5 rounds. At .85 probability of kill at 2000 meters this system would barely exceed the three vehicle kill requirement. Although figures were not available for a 120mm system, the length would also be pushing the transporting aircraft envelope. The decision for the LAAV is that since the 105mm will kill most modern tanks, at least in the top, flank, or rear, it is suitable for the mission. The assurance provided by the 120mm to kill all tanks frontally is not worth the trade-offs that may compromise the LAAV's overall mission in terms of transportability, but also in terms of onboard ammunition. A sensitivity analysis would likely show that the potential would exist for not meeting the lethality requirement because of onboard ammunition.

6.3 Survivability/Configuration Trade-Off Analysis.

The survivability of a tank is due to a combination of factors.¹³ These factors comprise the trade-offs in the configuration of the vehicle. The factors include: number of crewmen, location of the crewmen, placement or compartmentalization of components (engine,

¹³ Mark Reches and Benson King, pp. 33 through 35.

gun, fuel, ammunition, etc.), profile, armor, speed, and any countermeasures used such as smoke generation, chemical protection systems, low observable technology and others. The areas that are to be examined on the LAAV are number and location of crew, compartmentalization, and armor. To examine the other areas is beyond the scope of this project and starts to enter areas of classified information.

Criteria. The examined areas are to be rated by the following criteria in the order of importance: overall size and weight, operational fightability, protection to crew. Each of the three criteria are very important and are very close in importance. The reason for the priority is it does no good to have a system if it can not get there first. Once it is there, it does no good to have a system that can not be fought. Once the fight starts, the protection of the crew becomes the most important. It would seem intuitive that crew protection should be number one, however war is an inherently dangerous business and there is no possible way to provide absolute protection. In some cases, the trade-offs will be counter to each other. For example, hanging more armor on the vehicle to provide crew protection increases weight. However, placing the crew in the hull instead of in a turret not only lowers weight, but also decreases profile and also therefore increases crew protection. As you can see, the latter trade-off is complementary.

Crew Considerations. As mentioned in the previous paragraph, crew considerations have significant impacts on all three criteria. There are several choices concerning the crew.

Crew Size. The first choice is, how many crewmen should the LAAV be designed for? Traditional tanks have three or four crewmen. It is technologically feasible to have one. The fewer crewmen a tank has significantly reduces the weight and size as space under armor, required to protect each crewman, is a size and weight driver. However having fewer crewmen also has tremendous human factors engineering concerns. For example, there are still crew duties to be divided among the crew members such as maintenance, security, communications and the like. The crew must still attempt to sleep and eat in order to physically function. These factors do not disappear with smaller crews. The issue then becomes, how might the crew responsibilities be effectively spread among the smallest number of crewmen? There is also a psychological factor. It is now standard knowledge that, in battle, men fight more for themselves and their comrades than for sociological factors such as God and country. To reduce the crew to one ignores these factors. Therefore the one crewman configuration will not be considered. Conversely, four crewmen impose unacceptable size and weight additions. Consequently, the only numbers of crew that will be considered are three or two.

Crew Size Trade-Off. Since one and four man crews have been eliminated from consideration because of the selection of an auto loader and for battle psychology reasons; and there will have to be a vehicle driver regardless of configuration, the crew size issue is reduced to can one soldier perform the gunner and the vehicle commander's duties simultaneously? If he can, the tank can be much smaller and lighter. This is a human factors concern in terms of task performance. Essentially, the vehicle commander performs

communications, target selection, and tactical decision making. The gunner precisely lays the weapon on target and destroys it. The Army has indirectly acknowledged that one soldier can do both. On current tanks, the gunner station can be overridden from the commander's station. The rationale is that the commander may select a more important target or the gunner may be incapable of performing because of wounds. The second half of the rationale is the key to the decision because the Army tacitly admits the vehicle commander can perform both actions. Further, the gunner is trained to perform both gunner and commander duties in the event the commander is incapable. Thus the commander and the gunner become systems in parallel to allow for graceful system degradation in combat. The LAAV is not intended to be the ideal armor combat system. It can not afford the best of all operational worlds due to the severe transportability constraints imposed on its design. Therefore, since size and weight can be dramatically reduced by using two instead of three crewmen, and this size and weight reduction synergistically reduces vehicle profile, increases speed and thus increases survivability, the two crewman configuration is selected.

Crew Location. The second survivability/configuration choice concerning the crew is the location of the crew in the vehicle. Again there are choices. Conventional tanks have the crew, except the driver, in a turret or "armor basket." This is possible when size and weight are not severe constraints. The second option is to drop the crew into the hull. This provides the advantages of placing them at a lower profile and allowing components to be placed around them to provide protection. Placing the crew in the hull is made possible by two relatively new technologies: in-arm suspension

and electric drive transmission. Since we earlier selected electric drive and a low/no volume turret, there is no need to consider placing the two man crew in the turret because one would not exist. There is the issue regarding selecting in-arm suspension. There really is no question. The in-arm suspension is now in the second generation of its technology and is the design standard.¹⁴ The other choice is the older, heavier, and space consuming torsion bar technology. By removing the weight and space of the torsion bar systems and replacing them with the lighter and more compact in-arm shock damping systems, it is possible to place the crew deeper into the hull profile. Consequently, in arm suspension of the 27 kilo Newton class is selected for the LAAV.

Compartmentalization. The issue in compartmentalization is basically deciding the best configuration location between the crew, weapons, ammunition, engine, and fuel. Since the tank is necessarily so light and small, the criteria for compartmentalization will be protection and function, in that order. Obviously, function is relative. Only an unworkable functional solution would be unacceptable. Restated, if it is functionally possible to engineer a configuration and the crew can perform adequately in that configuration, the feasible configuration that provides the most protection will be selected.

Configuration Trade-Offs. The first configuration trade-off is the location of the engine. It is possible to place the engine in either the front or the rear. This choice is further facilitated by

¹⁴ R.M. Ogorkiewicz, "Novel hydropneumatic suspension.", International Defense Review., March 1989.

electric drive which may place the transmission in the rear or front, uncoupled from the engine, if desired. The crew has a better field of view if the engine is in the rear and there are some improvements in tractive power for engines located in the rear. Additionally, if the engine is in the rear, the gun may be depressed to a greater degree, which is a key design factor for defensive fires. This factor allows a greater portion of the tank to be terrain hidden in a defensive scenario thereby presenting a smaller target profile. Also, if a tank can obtain higher ground and depress the gun sufficiently, the tank can lethally attack the light top armor of an adversary. These concerns are mitigated by the small and compact size of the wankel engine. However, the crew is much more survivable with a front engine location. This is because ammunition and fuel may be stored in the rear away from the crew and further from potential shot lines. The rear placement of the fuel and ammunition also facilitates the "blowout" design, should the fuel and ammunition ignite, as well as logistical resupply. The fuel and ammunition compartments may be designed to blow away from the crew. Finally, the engine itself acts as additional armor. Since, both designs are feasible and functional but the front engine design is far more survivable, the front engine configuration with fuel and ammunition in the rear is selected for the LAAV. The placement of the electric drives may be in the front or rear as necessary to meet performance and/or transportability constraints. This final configuration places the crew in the hull behind the engine in the front and directly in front of the weapon and auto loader. The fuel and ammunition is then in the rear behind the weapon and auto loader. A conceptual drawing of the configuration of the tank is shown in figure 11.

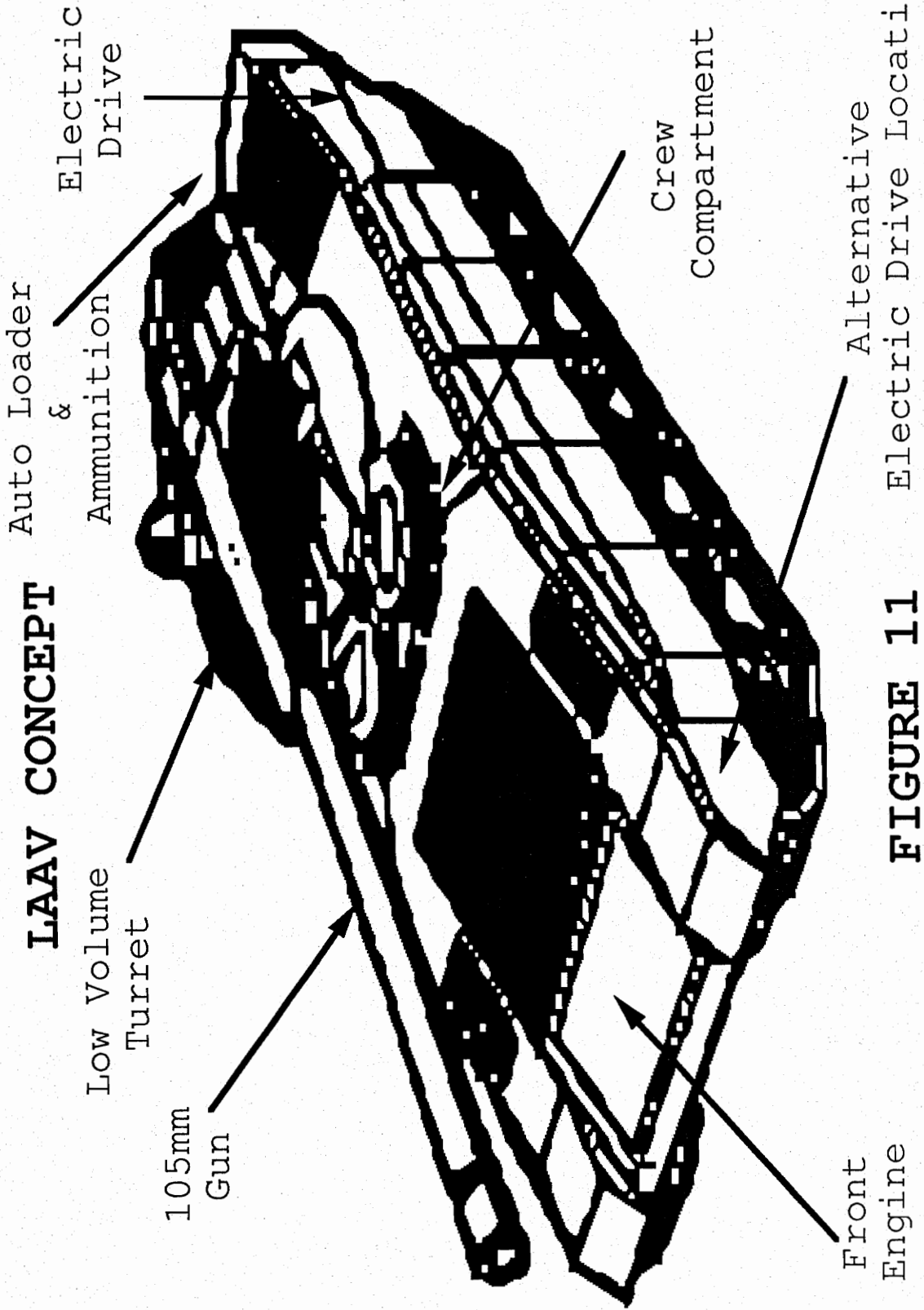


FIGURE 11

Electric Drive Location

Armor. There are too many choices concerning armor to make within the confines of this study. Additionally, most armor recipes are highly classified under Special Access Programs. However, discussion of armor is warranted. Some basic types of armor are rolled homogeneous steel, reactive, composite, laminated, and electromagnetic. Each has different size, weight, cost, production, and performance optimization characteristics. Armor historically comprises 45% to 54% of the weight of tanks.¹⁵ The design of the LAAV has intentionally sought to reduce that weight. 15% to 22% of the tank weight has traditionally been turret armor. Since the LAAV has no turret, only a weapon with protection, it is envisioned that the LAAV will have only 5% of the weight in turret armor. Further, 30% to 32% of tank weight has traditionally been hull armor. The LAAV has reduced this through front engine design and rear ammunition and fuel design. Lighter composites may now be placed in the rear of the tank as the fuel and ammunition are designed to blow out when hit anyway. FMC Corp. featured a Bradley Fighting Vehicle, the Army's current infantry fighting vehicle, at the 1989 Association of the U.S. Army (AUSA) convention, that was armored with composites to the same protection level as the current aluminum armor. The result was a weight reduction from 12,300 lbs to 9000 lbs for the hull structure; or a 27% weight reduction for structure alone. About 85% of the hull surface was made of a glass fiber composite.¹⁶ Composite protection in the rear, top and sides would only be provided up to 75mm Rocket Propelled Grenade (RPG)

¹⁵ Figures taken from a briefing by Colonel Ralph Barkman, Director Special Projects, HQ AMC, entitled "Protection versus Weight Tradeoffs." The briefing was presented to numerous U.S. Army executive level decision makers during 1988.

¹⁶ "If Real Ones Are Plastic, Will Models Be Metal?" Armed Forces Journal International, p. 21.

protection level. Since the engine provides ballistic protection in the front, lighter laminated armors can be used to provide protection levels to the crew up to 125mm at 1500 meters for the frontal 60° arc of protection. Finally, since the crew of two sits side by side or tandem in the hull, they may be encapsulated in an armor "bathtub" providing minimal space under armor. It is envisioned that these changes in design can reduce hull armor weight significantly, hopefully in the 25% range, which is not even as great a reduction as the FMC composite armored Bradley vehicle. All of this is in addition to the fact that the profile of the vehicle, both front and side, is substantially reduced. Thus the LAAV presents a harder to spot and harder to hit tank. Even with unknown armor weights, using the traditional weight percentages it is possible to parametrically estimate the weight of the LAAV to be in the 10 to 11 ton range. Using the unique configuration designs previously discussed, the weight could reasonably be expected to be less. This is significant, recalling that the required weight ceiling is 23.45 tons and the desired ceiling is 11.45 tons. Thus, it is feasible to meet the desired vehicle weight ceiling which facilitates battlefield helicopter transport if necessary.

6.4 Concept Recapitulation.

Based on the trade-off analysis, the LAAV will have the following design characteristics. The LAAV will be a two crewman, light armored vehicle in the 10 to 11 ton weight range. It will be powered by a front engine 750 horsepower wankel engine with electric drive transmission either in the front or rear. It will be armed

with a 105mm tank gun in a low/no volume turret configuration with an auto loader. Additional armament will be either .50 caliber or 7.62mm machine guns for light or troop targets. The machine gun will be mounted coaxial to the main gun to make use of the fire control system. The ammunition and fuel will be stored in the rear of the vehicle with blowout paneling. The armor in the front will be laminated conventional in the frontal 60° arc of protection with composites in the sides, rear, top, and bottom. The crew will be encapsulated in an armored "bathtub."

6.5 Non-Developmental Items.

A market survey was conducted among various armored vehicle producers to determine if a suitable "off the shelf" LAAV existed.¹⁷ There are some potential candidates; but none came close to meeting the stringent combination of lethality and transportability requirements. Because most candidates were conventionally designed, causing the weights of all investigated systems to exceed the desired range, none were deemed suitable for immediate adoption by the Army. The following companies were contacted: FMC, AAI, General Dynamics, Cadillac Gage TEXTRON, General Motors Defense,

¹⁷ The survey was conducted at the annual convention of the Association of the U.S. Army (AUSA) during the 16 through 18 October 1989 time period. The convention was attended by hundreds of domestic and foreign defense contractors. The project was explained to the industry representatives who either indicated they had possible candidates for a LAAV or not. Many had candidates and provided advertising literature from which the data were taken. The most notable contractors that had candidates were AAI Corp., FMC Corp., Cadillac Gage TEXTRON, Teledyne Continental Motors, General Motors, Hagglunds-Bofors, and Consorzio Iveco Fiat. There were other possible off shore contractors, particularly Brazilian, that it was not possible to interview.

Teledyne Continental Motors, Hagglunds/Bofors, and Consorzio Iveco Fiat. There are other on-shore and off-shore sources, but time limited further investigation. The candidates that were closest to meeting the desired requirement were provided by FMC, Cadillac Gage, and AAI. AAI's candidate came the closest in transportability but fell short in lethality. The AAI vehicle had two versions, both with conventional turrets around a 75mm gun. The two versions were a three man crew and a two man crew weighing 14.8 tons and 13.8 tons respectively. The AAI vehicle also had a rear mounted engine with a mechanical transmission connected to a diesel engine, all high weight subsystems and they still managed to approach the desired weight. Cadillac Gage's candidate weighed 22.25 tons, with a four man crew, a conventional turret, a 105mm gun, rear diesel engine, and mechanical transmission. FMC's candidate weighed 21.5 tons with a three man crew, conventional turret, 105mm gun, rear diesel engine, and mechanical transmission. Teledyne Continental Motors had a very interesting potential candidate. However, specific data were not available, but it used concepts that would indicate that it would be very close to meeting the desired specifications. The Teledyne Continental Motors Armored Gun System had a front mounted engine of some type that generated 500 hp, electric drive transmission, an auto loaded 105mm or 120mm main gun that had a 28 to 42 round capacity, a low volume turret, composite armor, and in-arm suspension. These were all of the available details on the Armored Gun System. This candidate would warrant further investigation to see if it could be modified to meet the requirement. Strictly, the onboard rounds would indicate a weight above 11 tons. It is therefore concluded that a new development must be undertaken to produce the LAAV.

7.0 Proposed Program Schedule.

There are many methods for depicting the proposed program schedule. The key to selecting which method is to determine which method best depicts the information that must be communicated to key individuals. The schedule is always linked to available funds, other assets (e.g. people, equipment), and technical feasibility. Some of the available methods are the Program Evaluation Review Technique/ Critical Path Method (PERT/CPM), Gantt Diagrams, and Swan Charts. The important factor is to demonstrate all of the key tasks of the program and their relationship to one another, especially in terms of time. The PERT/CPM method best shows detailed relationships between tasks and time but it is too detailed for this stage of the LAAV project. Therefore, the method selected for this project and report will be the familiar Gantt or milestone chart. The schedule for the LAAV is depicted in figure 12. The schedule coincides with the system life-cycle early years and addresses the phases of development, testing, decision reviews, and contract preparation. As with many other engineering disciplines, the computer has become an indispensable part of scheduling. There are numerous commercial programs on the market for assisting with scheduling such as Harvard Total Project Manager and MacProject by Apple Computer Company. As more detail is developed for the LAAV program these computer aids would certainly be used.

LAAV SCHEDULE

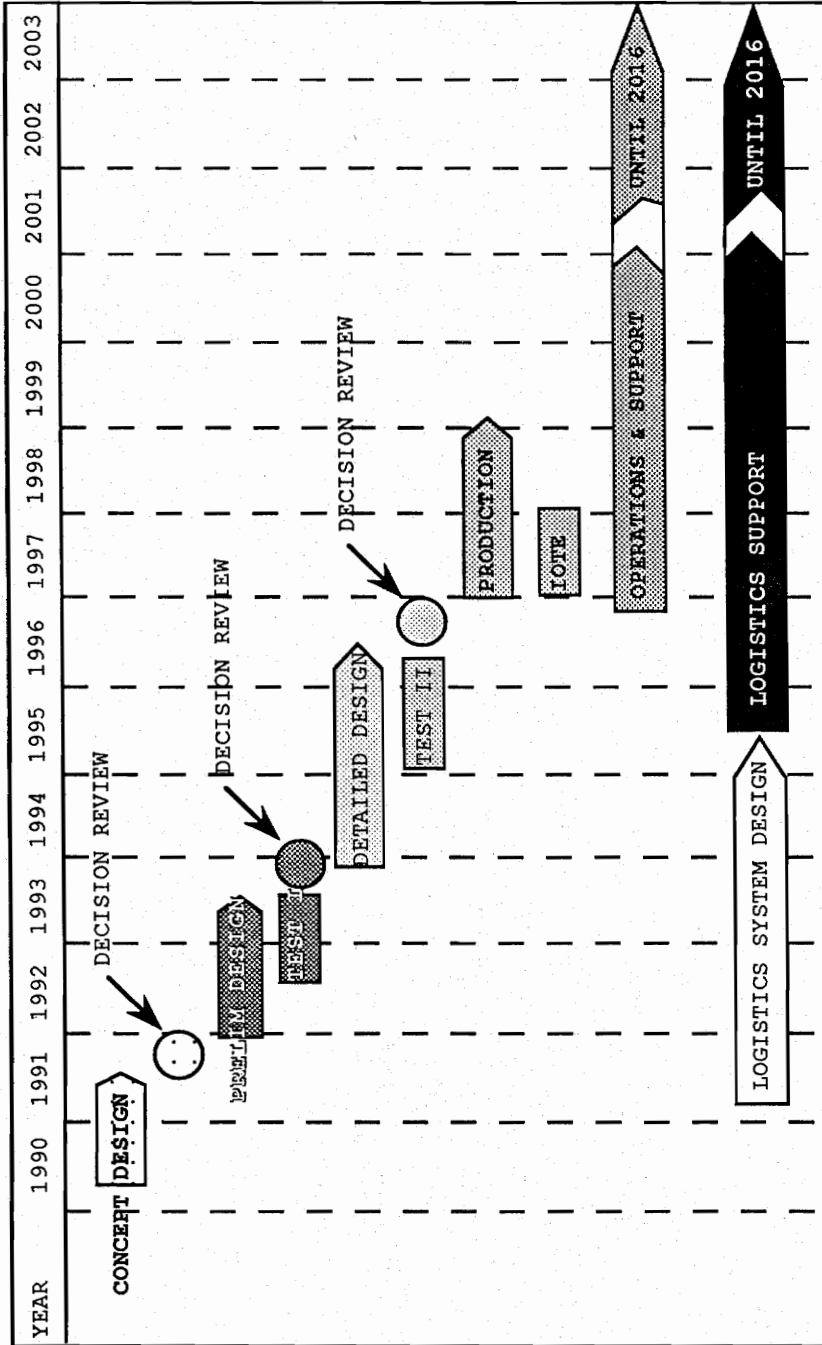


FIGURE 12

8.0 Preliminary Life-Cycle Cost (LCC) Analysis.

Cost estimation for a program is an attempt to accurately predict the cost of something that does not exist, except in concept. For this project and report, the Life-Cycle Cost (LCC) of the LAAV will be estimated. The life-cycle cost is the attempt to predict the total cost of all of the system elements over its useful life. There are various costs that make up the LCC. Like peeling the skin off an onion, each type of cost measures a more fundamental cost of the system.

This cost is the most fundamental or core cost of the system and is defined as the dollars required to get the system out of the factory door. The key measurements of this cost are the management costs, hardware costs, software costs, non recurring start-up costs (usually to equip the production facility), and allowance for engineering changes in design at a late date.

The next cost level accounts for all of the areas in the flyaway cost and some additional costs. The additional costs are the costs of technical data, publications and technical manuals, contractor support service, support equipment, training equipment, and the training of factory personnel.

The next higher cost level is the procurement cost level. This cost accounts for all of the costs of the previous two categories with the addition of the cost of initial or provisioning spares to support the system.

The program acquisition cost is a still higher cost level. Like the previous levels it includes all of the costs already mentioned, and adds Research, Development, Test, and Evaluation costs and the cost to construct the facilities that the new system will require during the course of its life-cycle.

Thus, LCC is the most encompassing cost of the system. LCC includes all of the previously mentioned costs and adds two final costs. The first cost that is added, is the cost of operations and support. This cost includes post-production support costs and alone will usually account for about 60-70% of the systems total LCC.¹⁸ The final costs that are elements of the LCC are the disposal costs. These are the costs required to demilitarize, scrap, refurbish and sell or otherwise end the useful life of the system.

Cost Estimating Techniques. There are a number of cost estimating techniques, each a different approach to arrive at a similar answer. Each technique has its strengths and weaknesses, but all are accepted if applied correctly and with the appropriate facts and assumptions. The major types of cost estimating techniques are: Parametric Cost Estimating, the Analogy Method, Extrapolation from actual costs of current or prototype production, engineering cost estimation by costing ever smaller components of the system, and other techniques such as the Delphi Process, Best Guess, and Bayesian Statistics.¹⁹ Often these methods are used in conjunction with computer technology such as modeling or simulation.

¹⁸ Benjamin S. Blanchard, Class notes from Engineering 5050, "The System Engineering Process.", Blacksburg, Va., February 1988.

¹⁹ Defense Systems Management College, The Program Manager's Notebook, Ft. Belvoir, Va., March 1989, pp. 2.3b & c.

Parametric Cost Estimating. This method is the most appropriate cost analysis technique to be used during the early phases of development of a system because a detailed design is not required. It is accomplished by using a data base of like cost elements and generates the cost estimate based on some selected system performance or design characteristic or characteristics. This is accomplished by generating a Cost Estimation Relationship (CER) with cost being the dependent variable and the design/performance parameter the independent variable. There are several keys to a good parametric cost estimation. The data base should reflect like technologies. That is, the characteristics of a light armored vehicles used to form the CER's should be developed from a data base of other light armored vehicles characteristics. Likewise, characteristics of a fighter aircraft should not be compared to a characteristics of a submarine. The data base must be timely. Electronic components are subject to rapid technological advance, and size and cost reduction, for example. Finally, the data base must be homogeneous. All relationships must be in the same units such as pounds, horsepower, km/second, and the like. To violate this causes loss of credibility and is often referred to as comparing apples to oranges. The parametric cost estimating technique is a gross estimating technique and is good to an order of magnitude.

Analogy Method. Another gross estimation technique is the Analogy Method. It is also appropriate in the early design phases of a system. This method compares a new system with an existing system for which we have accurate cost and technical data. The systems are usually compared on a one-for-one basis and subjective

assessment is made to the complexity increase or decrease of the new system by the design engineers. This complexity factor is applied to the cost of the known system and then added to the known system cost to arrive at the new system cost, after applying a time value of money inflation. For example, if a five year old car cost \$1000, the engineers estimated the new car to be 20% more complex and inflation had been 5% over the five years the cost of the new car would be as follows:

$\$1000 + (.20) (\$1000) = \$1200$ unadjusted for inflation. Adjusted for inflation at 5% for five years would be $(\$1200) (1.05) (1.05) (1.05) (1.05) (1.05) = \1531 .²⁰ Uncertainty is induced into this method due to the subjective nature of the complexity evaluation.

Extrapolation From Actual Costs. This method is appropriate for use later in the development phases all the way through production and deployment. It can be the most accurate method because it uses actual data on the investigated system from previous system units. This method uses learning curve techniques. Adjustments can be necessary when comparing production models to prototypes if there are significant process or materials differences.

Engineering Method. This method is the most detailed and difficult cost estimate to use. It is appropriate only during the later phases of the system life-cycle after there is a detailed design. It uses the Work Breakdown Structure and examines the cost starting with the lowest elements and cumulatively adding them up. Very often error can be induced in this type of cost estimate

²⁰ Example adapted from The Program Manager's Notebook, p.2.3b.

because the addition of all of the elements may not account for efficiencies or conversely may not count hidden expenses or synergistic costs.

LAAV LCC Cost Estimate. Since the LAAV is a developmental system with no detailed design, but is also a new type of system, obtaining a defensible cost estimate is most difficult. Ideally, a parametric estimate or an analogous estimate would be the most appropriate choice of methodology. It was not possible to obtain performance data from similar vehicles to form CERs since there are no similar vehicles. Likewise, there is no vehicle from which to draw an analogy. Further, there has been no prototype production or low rate production to use extrapolations. Therefore, the engineering method, although misapplied in terms of the system development maturity, is the only possible solution. To apply this method the Defense Systems Management College FORTRAN IV based Cost Analysis Strategy Assessment (CASA) Models were used.

The CASA Model.²¹ The CASA model was developed from the Honeywell Corporation's Total Resource and Cost Evaluation (TRACE) family of logistics support and LCC models. Thus it may be used in Design to LCC studies. Specifically, the Life-Cycle Cost Module of the CASA model was used. Estimates were made for the inputs that were best guesses formulated by investigating current infantry carriers. Although a different class of vehicle, infantry carriers are close in terms of drive train and weight. The LCC Module of CASA fits nicely with the preliminary LAAV system baseline. The

²¹ The descriptions of the components of the CASA model were paraphrased from the model documentation.

limitations of CASA are established in the documentation for the program and do not conflict with the LAAV baseline. These limitations are that the model restricts a system to three (3) maintenance levels, ninety eight (98) prime hardware items such as line replaceable units (LRUs), twenty (20) items of support equipment, and a study life of three hundred and sixty (360) months. The last limitation allows the life-cycle to be investigated for thirty (30) years. With the six (6) year development schedule and a twenty (20) year usable life established in the LAAV baseline, the model even has some growth potential when investigating the LAAV.

CASA Inputs. The inputs to the CASA model provide a reasonable investigation of potential LCC. The inputs include two major areas: acquisition costs and operations and support costs. The model inputs general system information such as study life, operating hours per month per system, operator requirements, inflation, discounting, and reliability growth parameters. CASA inputs maintenance information that includes quantity of systems supported per location, labor rates and spares. System production and cost data input include installation costs, system costs, learning curve, and rate curve. CASA also investigates system deployment data, other production data, research and development costs, transportation data, technical documentation data, training data, facilities data, item management data, warranty data, and other miscellaneous data. The system hardware data inputs include unit cost, MTBF, MTTR, spares turnaround time, removal and repair levels, re-test okay factor, material cost per repair, not repairable this station factors, condemnation factors, and scheduled maintenance considerations. Finally, the support equipment data inputs included

unit cost, maintenance costs, and utilization factors. Obviously, at such a level of detail many of the inputs are best guess or Delphi estimates for a non-existent system for which there is no predecessor system. Where possible the estimates were made by considering currently fielded U.S. Army systems that would be close in size, power, weight, etc.

CASA Outputs. The LCC module of the CASA model has five optional outputs. These outputs are complete life-cycle cost data, yearly cost data, support rationale by year, operational availability analysis, and operational availability with optimization of LRU spares. The outputs for the LAAV are found in the Appendices. The other Modules of CASA use the same input data. They include an LCC sensitivity analysis, an LCC risk analysis that uses a Monte Carlo simulation and develops distribution probabilities for the LCC instead of discreet values. This simulation has optional constant, normal, triangular, or uniform distributions. CASA also has a module to compare different runs of LCC. For programmatic decision making the sensitivity analysis and risk analysis modules are especially valuable.

CASA LAAV Results. After programming the CASA model with potential LAAV data inputs, possible LCC results were obtained. The total life-cycle cost of the LAAV over the twenty years of operation and including the six year development cycle is estimated to be \$3.1 billion dollars. The LCC is broken into acquisition costs, estimated to be about \$900 million, and operations and support costs estimated to be about \$2.2 billion. This LCC recapitulation is in Appendix A. This LCC estimate utilized the inputs located in

Appendix B. Of course, the LCC estimation would vary with different inputs. The ability to apply different inputs is the beauty of the CASA model. As a focus, the model seemed to be very sensitive to three inputs: production learning curve, transportation costs, and labor (operator and maintenance) manning and rates. While other parameters also cause change in the LCC, they fall into the noise category. This is especially pertinent since the model is used, in this case, to perform an order of magnitude early concept feasibility LCC estimate. The numbers are believable when viewed in two perspectives. First, the Acquisition costs comprise 29% of the LCC and the Operations and Support Costs comprise 71%. This tracks with accepted LCC cost theory.²² Second, the current Army budget is budgeting about \$5 billion for its current Heavy Force Modernization Program, which is a more comprehensive program over a similar time span.²³ When considering that the LAAV would be used to provide armor support to fully half the Army's combat assets, assets that are currently lacking any armor support, the costs would appear to be thrifty in comparison to Heavy Force Modernization.

LCC Sensitivity Analysis. Sensitivity analysis on the LCC was run for three parameters: Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and Unit Cost (UC). The CASA model allows the use of four mathematical distributions to accomplish this: normal, constant, triangular, or uniform. For purposes of this estimation the normal distribution was selected. In essence, the model estimated a range of LCC outcomes, based on the selected distribution, in the event that the selected parameters varied from

²² Benjamin S. Blanchard, class notes.

²³ Precise figure may not be given. However, this is personal knowledge.

50% of estimated to 150% of estimated. This investigation included components and the total system. The range was a variable selected by the operator and can vary as much as desired. The standard deviation of the selected distribution is also a selectable variable. For this study, if the parameters varied for the total system or for individual subsystems, the LAAV system seemed to be relatively insensitive to variations in UC and MTTR. The LAAV was much more sensitive to variations in MTBF, but did not display a gross variation in this order of magnitude LCC. The full sensitivity output is in Appendix C, but Table 3 provides abbreviated LCC results.

TABLE 3 LCC SENSITIVITY

<u>PARAMETER</u>	<u>LOW</u>	<u>BASELINE</u>	<u>HIGH</u>
UC	\$2.7B	\$3.1B	\$3.5B
MTTR	\$2.9B	\$3.1B	\$3.3B
MTBF	\$2.3B	\$3.1B	\$5.3B

Therefore it is noteworthy that the only sensitivity to the program decision process is if the MTBF of the system or its components is actually delivered at 50% of design. It must be kept in mind that even if this happens, the cost will be spread over 26 years.

Risk Analysis. The CASA model also performs risk analysis based on the same three parameters as the sensitivity analysis. Again, the modeler can select what type of distribution he will use for each parameter. The model then runs a Monte Carlo simulation and provides a cumulative probability that the LCC will come in at a

particular number. For the LAAV, normal distributions for the components were selected due to the absence of real data. Time permitting, further investigation of similar armored vehicle components would be conducted to determine if a better probability distribution should be selected. With the selected normal probability distributions for components, the Monte Carlo simulation provided data that indicated that there was a cumulative probability that the LCC had a 95% chance of being \$3.35 billion over the 26 years of development and operation. The most frequently occurring LCC was \$3.04 billion. Both of these figures compare favorably with the projected LCC of \$3.1 billion. Tests have shown that Monte Carlo LCC frequency distributions are beta distributed.²⁴ The Chi-Square Goodness of Fit test confirms this to be the case for the LAAV. The test statistic is 3.687 and is significant at the .60 level. Thus, the beta distribution is a good fit. 500 runs were made to insure the simulation was at steady state. Time permitting, CASA is capable of performing 1000 iterations. The results are in Appendix D.

Other LCC Estimation Support. Computer modeling is becoming essential to LCC analysis, although it can still be done via stubby pencil. There are wide varieties of models available and computer aided logistics (CALs) is becoming the wave of the future and will soon take its place as an equal with Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). It is also feasible to develop a system specific model using simulation techniques such as DYNAMO or SLAM II. The Defense Systems Management College has a research

²⁴ Defense Systems Management College, Cost Analysis Strategy Assessment (CASA) Models software documentation, September 1986, p. 10-3.

function devoted exclusively to improving the acquisition process as it relates to weapons systems. Part of this research function is developing a Program Manager's Support System for software support. They are currently developing an LCC estimation program called Parametric Cost Estimating (PACE) Module which will model that previously described technique. It will use a module called Parametric Cost Estimating Relationships (PACER), which will help to develop the CERs. Unfortunately, this model would be more appropriate for this stage of development of the LAAV. However, it is currently a prototype computer model and is not available for release.

9.0 Work Breakdown Structure.

The Work Breakdown Structure (WBS) is a key system engineering management tool and has many uses. It is basically a product oriented family tree composed of hardware, software, services, and data. It is the foundation for program and technical planning, cost estimation and budget planning, schedule definition, statements of work and specifications, progress status reporting, and problem analysis. It can be coupled with the management structure and used to form work packages. The work packages may in turn be used to monitor budget and or schedule expenditure. It can also be used as a basis for the functional allocation, maintenance allocation, requirements allocation, and many other purposes. In this project and report the LAAV WBS starts at the system level and is defined to the third level. However, it is possible to define the WBS to much more detailed levels. In fact the WBS may be defined in as much detail as is desired or as is necessary. The WBS for the LAAV is shown in figure 13.

LAAV WORK BREAKDOWN STRUCTURE

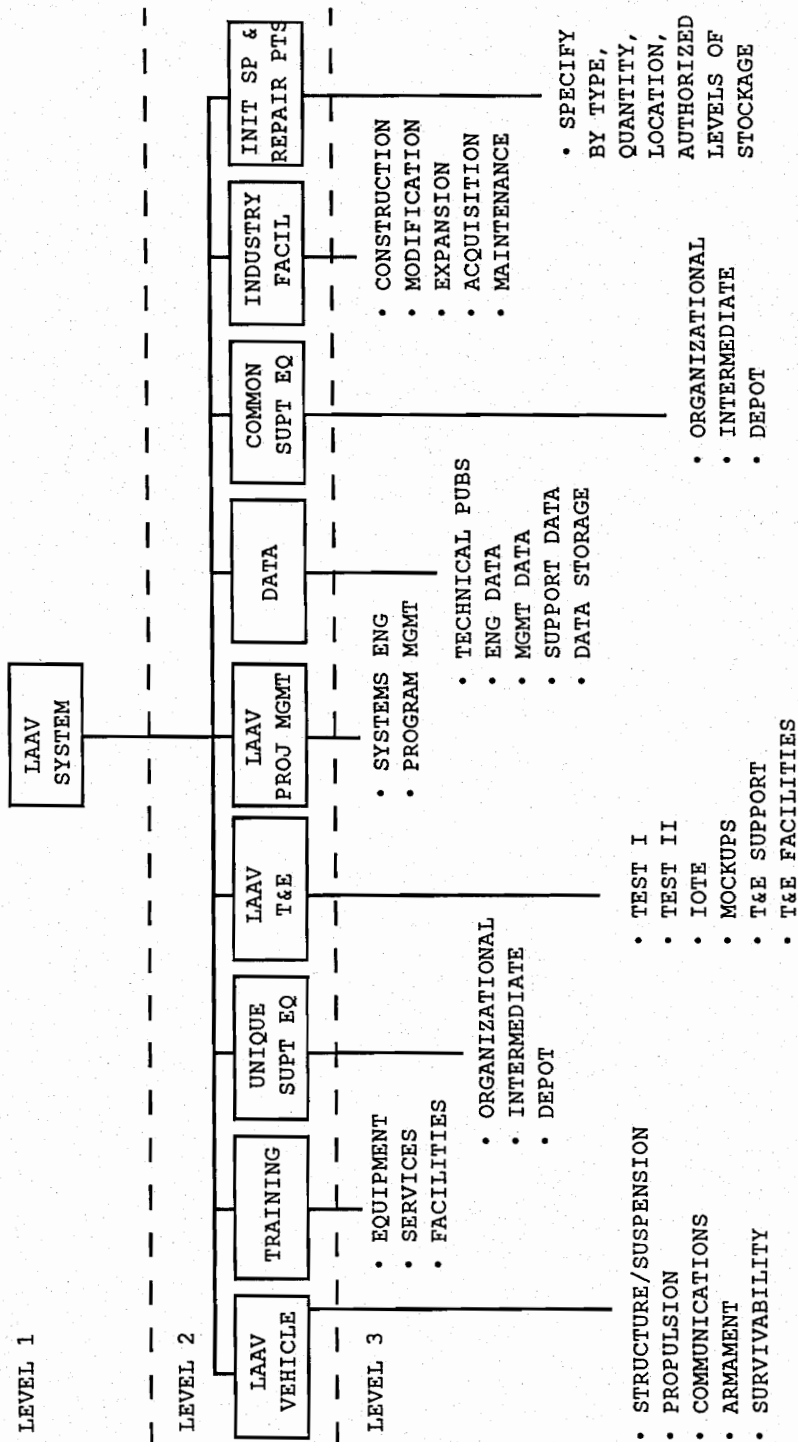


FIGURE 13

10.0 Summary.

The conclusion of this project and report is that the Army should immediately start development, production, and fielding of a Light Armored Assault Vehicle (LAAV), or similar system. The primary reason is that half of the Army's combat power has minimal ability to operationally sustain against armored forces. The likelihood of encountering armored forces is high in the mission scenario.

Technologically, there are no barriers preventing the development of such a system with known, producible, and low risk components. The cost, as with most combat system developments, will be expensive. However, when compared to the cost of modernizing the heavy forces it is a bargain. This particularly important when considering that the heavy forces must only be modernized and that there is no existing armor capability in the light forces. While understanding that advocacy must be built for the system, the current world political climate provides a more favorable opportunity to undertake such an endeavor than we have seen in many years. In a larger perspective, it is becoming evident that the nature of warfare has fundamentally evolved. This is nothing new as the art and science of warfare has always been dynamic, progressing sequentially from stone to spear, bow and arrow, gun, machine gun, and tank. This evolution merely continues a process that is ongoing and inevitable. It is often said that an army always prepares to fight the last war when in fact the next war will be different. The evolution now has clear definition as we examine the trends started with the Korean Conflict, Viet Nam, Grenada, and potentially Latin America and other third world regions. The decision is not that difficult when viewed in the context of the clear trends.

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APPENDIX A

(COST SUMMARY)

=====

COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0

=====

DEFENSE SYSTEMS
MANAGEMENT COLLEGE

DATA FILE USED: llaav.dat

Light Armored Assault Vehicle (LAAV)

01-01-80

=====

ACQUISITION COSTS

=====

TOTAL ACQUISITION COST

293229600.

=====

OPERATION AND SUPPORT COSTS

=====

TOTAL OPERATION AND SUPPORT COST

2213957000.

TOTAL LIFE CYCLE COST FOR 322 MONTHS..... 3107136000.

=====

APPENDIX B

(CASA MODEL LAAV INPUTS LIST)

COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0
 =====

LIST INPUTS PROGRAM

DEFENSE SYSTEMS
 MANAGEMENT COLLEGE

INPUT LCC DATA FILE: llaav.dat

01-01-80

Level 1 = ORGANIZATIONAL
 Level 2 = INTERMEDIATE
 Level 3 = DEPOT

NOTE: Numbers in parentheses following section headings
 denote references from CASA Users Manual

STUDY NAME (4.1): Light Armored Assault Vehicle (LAAV)

GENERAL INPUT INFORMATION (4.2)

Reliability Growth Option:	D (Duane)
Initial Year of Study:	1990
Year in Which Dollars are Expressed:	1990
Study Life (Months):	322
Cost Adjustment Factor:	1.000
MTBF Adjustment (Degradation) Factor:	1.000
Average Operating Hours per Month per System:	29.00
System Operator Required Portion:	2.00000
System Operator Labor Rate (\$/hr):	15.00
Support Equipment and Spares Factor:	1.000
Portion of Repair Time Spent on RTOK:	.150
Consumables Cost as Portion of Piece Parts Cost:	.010

Relative Year	Calendar Year	Inflation Rate (%)	Discount Rate (%)
1	1990	.000	.000
2	1991	5.000	10.000
3	1992	5.000	10.000
4	1993	5.000	10.000
5	1994	5.000	10.000
6	1995	5.000	10.000
7	1996	5.000	10.000
8	1997	5.000	10.000
9	1998	5.000	10.000
10	1999	5.000	10.000
11	2000	5.000	10.000

12	2001	5.000	10.000
13	2002	5.000	10.000
14	2003	5.000	10.000
15	2004	5.000	10.000
16	2005	5.000	10.000
17	2006	5.000	10.000
18	2007	5.000	10.000
19	2008	5.000	10.000
20	2009	5.000	10.000
21	2010	5.000	10.000
22	2011	5.000	10.000
23	2012	5.000	10.000
24	2013	5.000	10.000
25	2014	5.000	10.000
26	2015	5.000	10.000
27	2016	5.000	10.000

Duane Growth Parameters:

Duane Growth Type:	P (Pure)
Starting Hours:	1000.
Duane Growth Slope:	.2200
Beginning MTBF Portion:	.0100
Maximum MTBF Portion:	1.0000

MAINTENANCE LEVEL INFORMATION (4.3)

	Level 1	Level 2	Level 3
	-----	-----	-----
No. of Operating Systems per Loc.:	58.	116.	696.
Maintenance Labor Rate (\$/hr):	13.00	25.00	35.00
Available Support Equip. Hours per Mo.:	160.	160.	160.
Support Equipment Utilization Factor:	1.00	1.00	1.00
Initial Spt Eq Spares Cost Portion:	.10	.10	.10
Spares Confidence Level:	.95	.95	.95
Earned Hour Ratio:	1.00	1.00	1.00
System Repair Elapsed Time (Hours):	4.00	96.00	336.00

SYSTEM PRODUCTION AND COST DATA (4.4)

Previous Quantity of Systems Produced:	20.
Base Unit Cost per System (\$):	1000000.00
Installation Cost per System (\$):	500.00

Year	Quantity Produced	Quantity Slope	Rate Slope
2000	220.	.9000	.9500
1999	600.	.9000	.9500
1998	570.	.9000	.9500
1997	115.	.9000	.9500
1996	1.	1.0000	1.0000

SYSTEM DEPLOYMENT DATA (4.5)

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1996	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
1997	2.	2.	2.	2.	5.	5.	5.	10.	15.	18.	24.	25.
1998	30.	40.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
1999	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
2000	50.	50.	50.	30.	20.	10.	10.	0.	0.	0.	0.	0.

PRODUCTION TOOLING AND TEST EQUIPMENT (4.6)

Name	Year	Cost
Multi Axis Machine	1995	10000000.00

PRODUCTION START-UP COST (4.7):

Year for Production Start-up:	0
Production Start-up Cost:	10000000.00

SYSTEM SHIPPING AND STORAGE CONTAINERS (4.8)

Year When Cost Incurred:	0
Number of Containers:	0.
Unit Cost:	.00

PRE-PRODUCTION NON-RECURRING ENGINEERING COSTS (4.9)

Name	Year	Cost
Test Fixes	1996	1500000.00

PRE-PRODUCTION REFURBISHMENT COST (4.10)

Year in Which Cost Incurred:	0
Quantity of Units Refurbished:	20.
Average Cost per Unit:	150000.00

SYSTEM HARDWARE DATA (4.11)

List of Abbreviations:

COND : Portion of failures expected to be condemned
 DPT : Depot level
 INT : Intermediate level
 K : Adjustment (Degradation) factor for MTBF
 LREM : Primary Removal Level
 LRPR : Primary Repair Level
 MCPR : Material cost per repair
 MTBF : Mean time between failures
 MTTR : Mean time to repair
 NRTS : Portion of failures not repairable at the primary repair level
 ORG : Organizational Level
 QPNHA: Quantity per next higher assembly
 RTOK : Portion of failures expected to retest okay
 TAT : Turnaround time in months

1) No.	Item Name	Type	Unit Cost	QPNHA	MTBF	K	MTTR					
2) Weight (Lbs)	---Spares TAT---								NRTS	COND		
	ORG	INT	DPT	LRPR	LREM	RTOK	MCPR	NRTS	TAT	COND	TAT	
1) 1	LAHV			0	1000000.00	1	200.	1.000	4.00			
2) 22000.00	.00	.03	.23	1	3	2.000	50.00	.000	1.00	.000	1.00	
1) 2	INTEGRATED FIRE CNTL			1	10000.00	1	10000.	1.000	1.00			
2) 500.00	.00	.02	.03	1	1	2.000	25.00	.000	.00	.000	.00	
1) 3	ELECTRIC DRIVE			1	20000.00	2	5000.	1.000	4.00			
2) 1000.00	.00	.23	.00	3	1	2.000	50.00	.000	.00	.000	1.00	
1) 4	ENGINE			1	100000.00	1	300.	1.000	10.00			
2) 2500.00	.00	.00	.23	2	1	2.000	100.00	.000	.50	.000	1.00	
1) 5	GUN SYSTEM			1	250000.00	1	2000.	1.000	24.00			
2) 3000.00	.00	.06	.23	3	2	2.000	250.00	.000	.00	.000	.50	

SUPPORT EQUIPMENT MAINTENANCE DATA (4.12)

No.	Name	Unit Cost	Annual Maint. Cost Portion
1	STD TEST SET	250000.00	.050

SUPPORT EQUIPMENT LOADING (4.13,4.14,4.15) (Average Hours/Maintenance Action)

Level 1

Item	Support Equipment Number
1	

LAAV 3.00

Level 2

Item		Support Equipment Number
	1	
LAAV	3.00	

Level 3

Item		Support Equipment Number
	1	
LAAV	1.00	

TRANSPORTATION COST DATA (4.16)

Cost (\$) per Pound Between:

Organizational and Intermediate Levels:	.100
Organizational and Depot Levels:	.100
Intermediate and Depot Levels:	.100
Depot Level and a Factory Depot:	.150

Paperwork and Packaging Cost per Trip: 100.000

REUSABLE SPARES CONTAINERS (4.17)

Name	Year	Cost
None Identified	0	.00

INITIAL TECHNICAL DOCUMENTATION (4.18)

Document Name	Year	Number of Pages	Cost per Page		Number of Copies
			Developing	Publishing	
PARTS MANUAL	1996	500	250.00	.050	1000.
MECHANICS MANUAL	1996	500	250.00	.050	500.
OPERATOR MANUAL	1996	250	500.00	.050	2000.

RECURRING TECHNICAL DOCUMENTATION (4.19) (Per Year)

	Level 1	Level 2	Level 3
	-----	-----	-----
Number of Pages Revised:	15.	2.	1.
Cost per Page:	250.00	250.00	250.00

INITIAL TRAINING (4.20)

Per Diem Allowance per Day per Trainee (\$): 54.00
 Avg. Round-trip Transportation Costs (\$): 400.00

Initial Training Courses

Course Name	Year	Days	Class		Trainees		Instructors	
			Hours	Development Cost per Class Hr.	Number	Labor Rate	Number	Labor Rate
LAAV Crewman Course	1997	7.	40.	500.00	4000.	45.00	5.0	60.00

RECURRING TRAINING (4.21)

	Level 1	Level 2	Level 3
New Personnel Training Hours:	40.00	15.00	5.00
Development Cost per Hour:	500.00	500.00	500.00
Annual Turnover Rate:	.50	.30	.20

TRAINING DEVICES (4.22)

Name	Year	Quantity	Unit Cost
COFT	1997	75.	1000000.00

NEW FACILITIES (4.23)

Name	Year	Number of Square Feet	Average Cost per Square Foot
NO NEW FACILITIES	0	0.	50.00

RECURRING FACILITIES (4.24)

	Level 1	Level 2	Level 3
Number of Square Feet:	4000.	4500.	5000.
Annual Cost per Square Foot:	10.00	10.00	10.00

INITIAL ITEM MANAGEMENT (4.25)

Year in Which Cost Incurred: 1997
 Quantity of New Parts or Assembly Types: 100.
 Cost per Unit to Introduce into Inventory: 5000.00

RECURRING ITEM MANAGEMENT (4.26)

New Piece Part and Assembly Types for Support

	Level 1	Level 2	Level 3
	-----	-----	-----
Quantity of New Parts:	100.	50.	15.
Yearly Cost per New Part:	1200.00	1200.00	1200.00
Total Quantity of Parts Stocked:	2.	2.	1.
Yearly Cost per Part per Loc.:	100.00	100.00	100.00

CONTRACTOR SERVICES (4.27)

	Year	Man- Months	Cost/Man- Month
Level 2	1997	0.	48.00
Level 2	1998	24.	12.00
Level 3	1997	0.	48.00
Level 3	1998	24.	12.00
Level 3	1999	12.	12.00

OPERATIONAL ENGINEERING CHANGES (4.28)

Year	Cost
1995	5000000.00
1996	2000000.00
1997	2000000.00
1998	1000000.00
1999	500000.00
2000	250000.00
2001	100000.00
2002	100000.00
2003	50000.00
2004	25000.00
2005	10000.00
2006	10000.00

MISCELLANEOUS ACQUISITION COSTS (4.29)

Name	Year	Cost
None Identified	0	.00

MISCELLANEOUS OPERATION AND SUPPORT COSTS (4.30)

Name	Level	Year	Cost
None Identified	0	0	.00

WARRANTY DATA (4.31)

Number of Warranty Years:	2
Number of Cost Categories Covered:	4

Cost Categories Covered by Warranty:

- 1 TOOLING AND T.E.
- 8 SUPPORT EQUIPMENT
- 9 HARDWARE SPARES
- 13 TRAINING DEVICES

Warranty Price:

Year	Cost
1997	1000000.00
1998	1000000.00
1999	1000000.00
2000	1000000.00
2001	1000000.00

APPENDIX C

(LIFE-CYCLE COST ESTIMATE SENSITIVITY ANALYSIS FOR
THE MEAN TIME BETWEEN FAILURE (MTBF), MEAN TIME TO
REPAIR (MTTR), AND UNIT COST (UC) PARAMETERS)

```

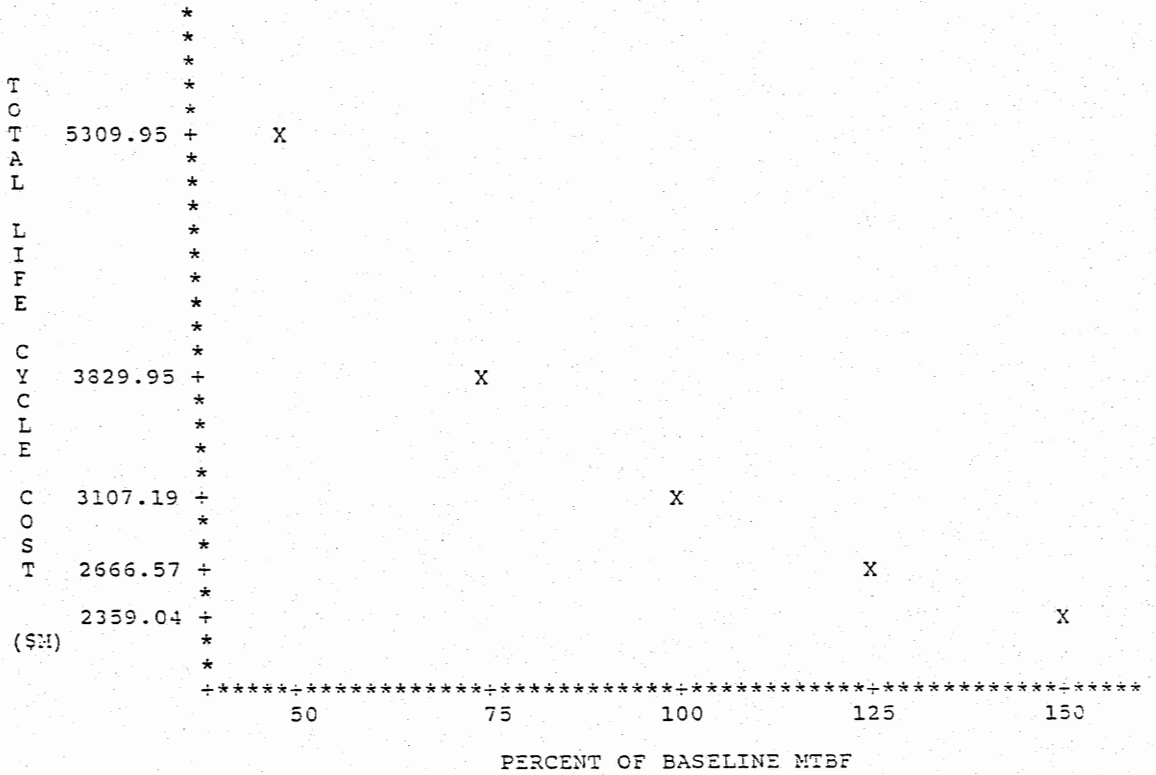
*****
*                                     *
*   MTBF SENSITIVITY GRAPH         *
*                                     *
*           LCC VS MTBF           *
*                                     *
*****
    
```

DATA FILE USED: llaav.dat

Light Armored Assault Vehicle (LAAV)

01-01-80

SENSITIVITY = 29509140. (\$ / MTBF %)



COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0
 =====

SENSITIVITY SUB-MODEL

DEFENSE SYSTEMS
 MANAGEMENT COLLEGE

DATA FILE USED: llaav.dat

Light Armored Assault Vehicle (LAAV)

01-01-80

RESULTS OF MTBF SENSITIVITY RUNS *

PERCENT OF BASELINE MTBF	ACQUISITION COST (\$)	OPERATION AND SUPPORT COSTS (\$)	TOTAL LCC (\$)
50.	1211525000.	4098426000.	5309950000.
75.	987829600.	2842122000.	3829951000.
100. **	893229600.	2213957000.	3107186000.
125.	828879600.	1837686000.	2666566000.
150.	772594600.	1586442000.	2359036000.

* THE MEAN TIME BETWEEN FAILURES (MTBF) OF EACH ITEM IS
 MULTIPLIED BY THE PERCENT OF BASELINE MTBF TERM TO OBTAIN
 THE MTBF VALUES USED IN EACH SENSITIVITY RUN SHOWN ABOVE.

** BASELINE MTBF RUN

```

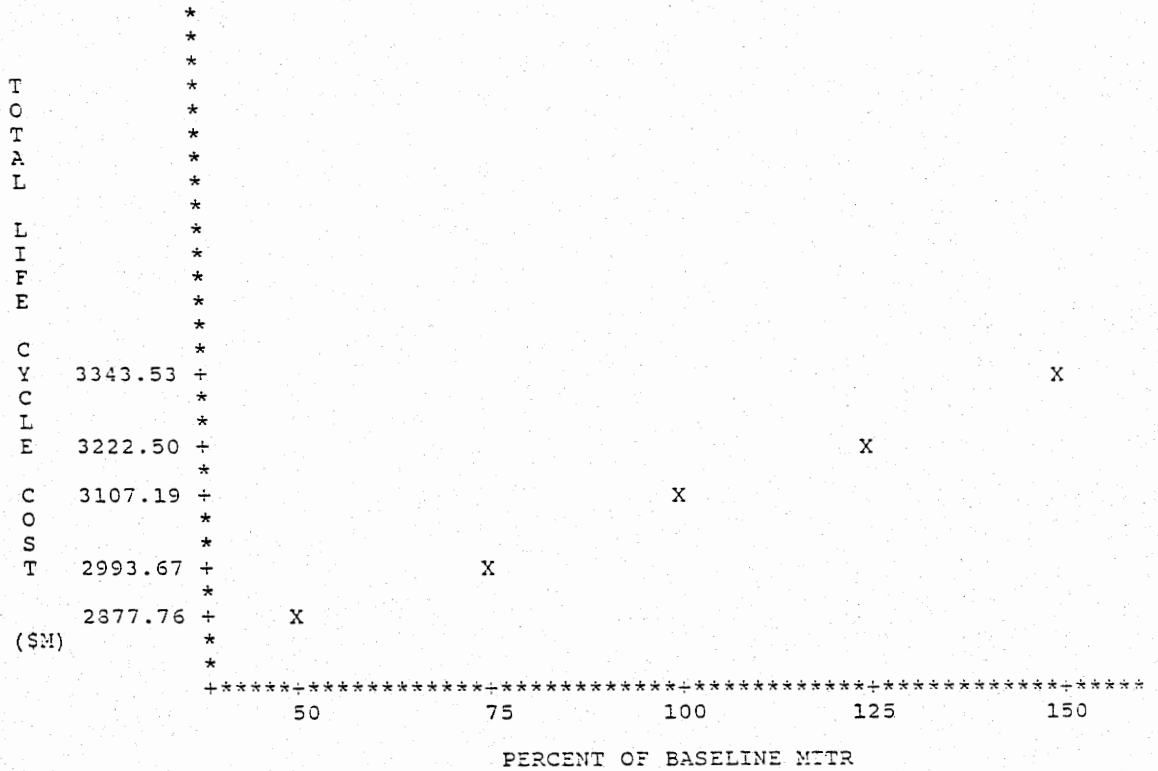
*****
*
*   MTR SENSITIVITY GRAPH   *
*
*   LCC VS MTR              *
*
*****
    
```

DATA FILE USED: llaav.dat

Light Armored Assault Vehicle (LAAV)

01-01-80

SENSITIVITY = 4657722. (\$ / MTR %)



COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0
 =====

SENSITIVITY SUB-MODEL

DEFENSE SYSTEMS
 MANAGEMENT COLLEGE

DATA FILE USED: llaav.dat

Light Armored Assault Vehicle (LAAV)

01-01-80

RESULTS OF MTTR SENSITIVITY RUNS *

PERCENT OF BASELINE MTTR	ACQUISITION COST (\$)	OPERATION AND SUPPORT COSTS (\$)	TOTAL LCC (\$)
50.	855279600.	2022481000.	2877761000.
75.	875354600.	2118311000.	2993665000.
100. **	893229600.	2213957000.	3107186000.
125.	912204600.	2310292000.	3222496000.
150.	937504600.	2406029000.	3343533000.

* THE BASELINE MEAN TIME TO REPAIR (MTTR) OF EACH ITEM IS MULTIPLIED BY THE PERCENT OF BASELINE MTTR TERM TO OBTAIN REPAIR TIMES USED IN EACH SENSITIVITY RUN SHOWN ABOVE. TIME REQUIRED ON EACH PIECE OF TEST EQUIPMENT IS ALSO MULTIPLIED BY THE PERCENT TERM.

** BASELINE MTTR RUN

```

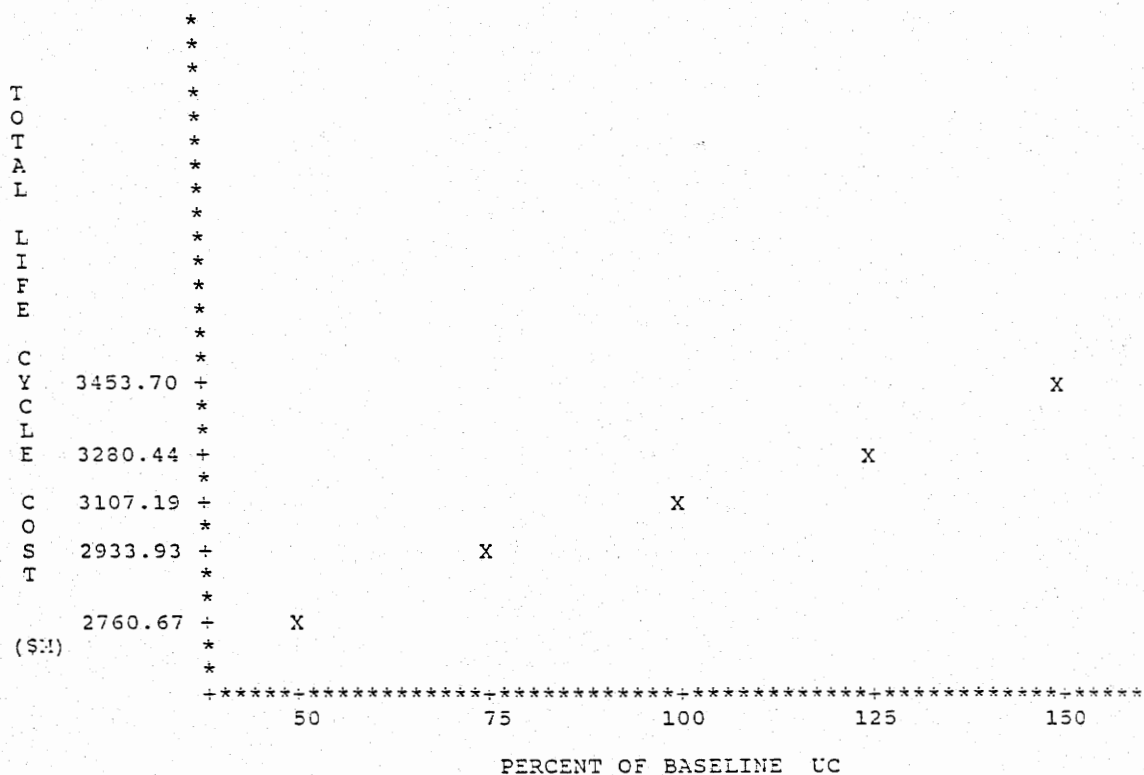
*****
*          UC SENSITIVITY GRAPH          *
*          LCC VS UC                     *
*          *                               *
*****
    
```

DATA FILE USED: llaav.dat

Light Armored Assault Vehicle (LAAV)

01-01-80

SENSITIVITY = 6930303. (\$ / UC %)



COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0
 =====

SENSITIVITY SUB-MODEL

DEFENSE SYSTEMS
 MANAGEMENT COLLEGE

DATA FILE USED: llaav.dat

Light Armored Assault Vehicle (LAAV)

01-01-80

RESULTS OF UC SENSITIVITY RUNS *

PERCENT OF BASELINE UC	ACQUISITION COST (\$)	OPERATION AND SUPPORT COSTS (\$)	TOTAL LCC (\$)
50.	546714600.	2213957000.	2760671000.
75.	719972100.	2213957000.	2933929000.
100. **	893229600.	2213957000.	3107186000.
125.	1066467000.	2213957000.	3280444000.
150.	1239745000.	2213957000.	3453702000.

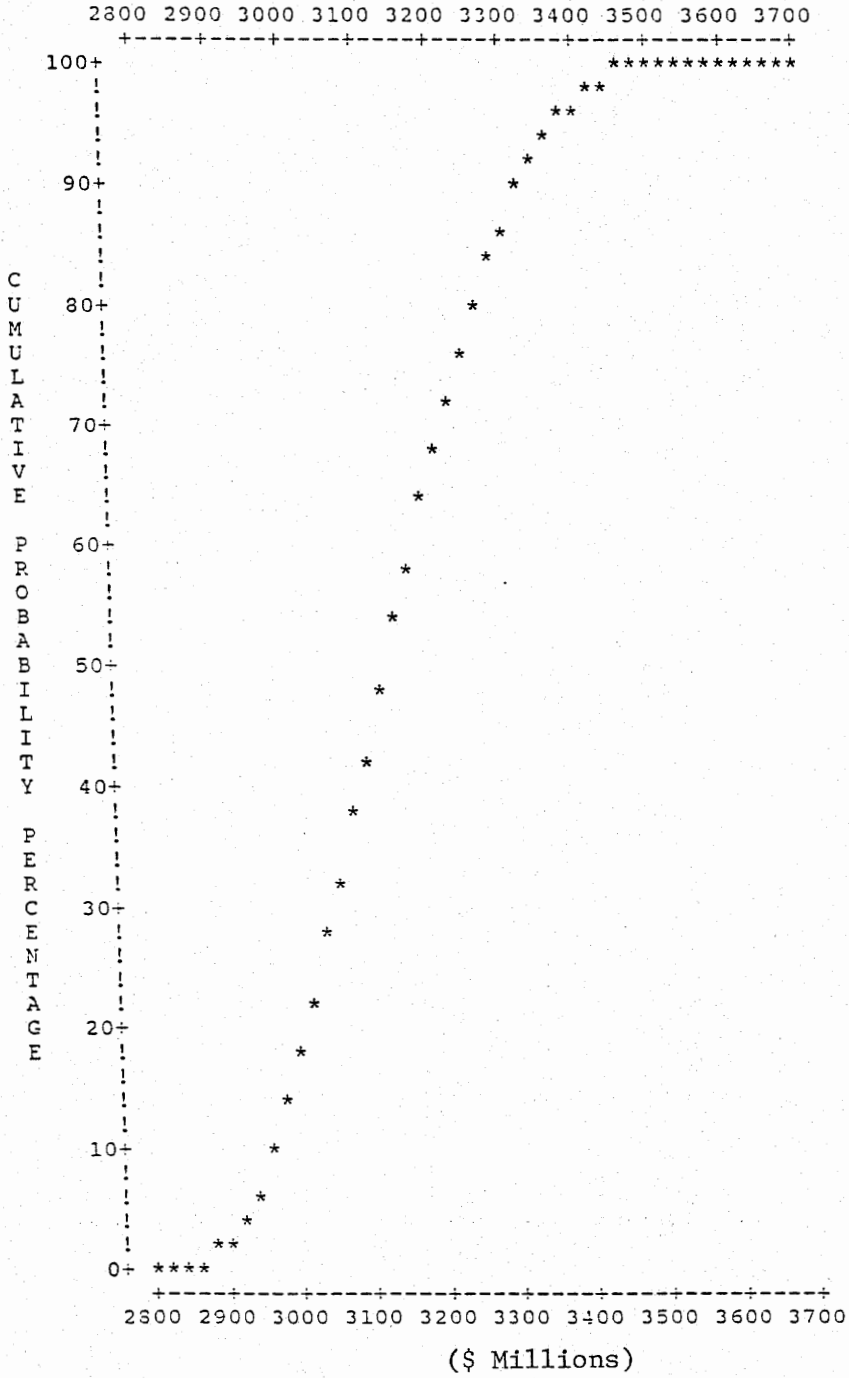
* THE UNIT COST (UC) OF EACH ITEM AND SYSTEM IS MULTIPLIED
 BY THE PERCENT OF BASELINE UC TERM TO OBTAIN THE UC VALUES
 USED IN EACH SENSITIVITY RUN SHOWN ABOVE.

** BASELINE UC RUN

APPENDIX D

(LIFE-CYCLE COST RISK ANALYSIS)

LCC VS CUMULATIVE PROBABILITY (USING THEORETICAL BETA DISTRIBUTION)



Light Armored Assault Vehicle (LAAV)

01-03-20

LCC MONTE CARLO RESULTS

Minimum	Maximum	Mean	Standard Deviation
2828151000.	3603033000.	3136472000.	137491600.

LCC Frequency Table

Cell Mid-point	Frequency
2871200000.	19
2957298000.	62
3043396000.	118
3129494000.	109
3215592000.	88
3301690000.	64
3387788000.	28
3473885000.	10
3559983000.	2

LCC Cumulative Distribution

Cell End-point	Cumulative Probability
2914249000.	.038
3000347000.	.162
3086445000.	.398
3172543000.	.616
3258641000.	.792
3344739000.	.920
3430836000.	.976
3516934000.	.996
3603032000.	1.000

Light Armored Assault Vehicle (LAAV)

01-03-20

Beta Parameters

Alpha Beta

2.63 3.98

Beta Cumulative Distribution

Cell End-point Cumulative Probability

2914249000.	.038
3000347000.	.179
3086445000.	.390
3172543000.	.613
3258641000.	.799
3344739000.	.921
3430836000.	.981
3516934000.	.999
3603032000.	1.000

Chi-Square Goodness-Of-Fit Test

I	Obs Freq	Exp Freq	((O-E)**2)/E
1	19	13.814	.002
2	62	70.455	1.015
3	118	105.777	1.412
4	109	111.588	.060
5	88	92.775	.246
6	64	61.227	.126
7	28	29.936	.125
8	12	9.427	.702

Chi-square test statistic is 3.637
 Test is significant at the .60 level

COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL --VERSION 1.0
 =====

RISK ANALYSIS SUB-MODEL

DEFENSE SYSTEMS
 MANAGEMENT COLLEGE

LCC DATA FILE USED: llaav.dat
 RISK DATA FILE USED: plaav.dat

Light Armored Assault Vehicle (LAAV)

01-03-80

RISK INPUT DATA

System Base Unit Cost

	Dist. Type	Parameter 1	Parameter 2	Parameter 3
Cost	Normal	1000000.00	10000.00	.00

Item Number 1 LAAV

	Dist. Type	Parameter 1	Parameter 2	Parameter 3
Cost	Normal	1000000.00	10000.00	.00
MTBF	Normal	200.00	20.00	.00
MTTR	Normal	4.00	.50	.00

Item Number 2 INTEGRATED FIRE CNTL

	Dist. Type	Parameter 1	Parameter 2	Parameter 3
Cost	Normal	10000.00	1000.00	.00
MTBF	Normal	10000.00	100.00	.00
MTTR	Normal	1.00	.25	.00

Item Number 3 ELECTRIC DRIVE

	Dist. Type	Parameter 1	Parameter 2	Parameter 3
Cost	Normal	20000.00	1000.00	.00
MTBF	Normal	5000.00	100.00	.00
MTTR	Normal	4.00	.25	.00

		Item Number 4	ENGINE		
	Dist. Type	Parameter 1	Parameter 2	Parameter 3	
Cost	Normal	100000.00	2000.00	.00	
MTBF	Normal	300.00	30.00	.00	
MTTR	Normal	10.00	1.00	.00	

		Item Number 5	GUN SYSTEM		
	Dist. Type	Parameter 1	Parameter 2	Parameter 3	
Cost	Normal	250000.00	1000.00	.00	
MTBF	Normal	2000.00	10.00	.00	
MTTR	Normal	24.00	6.00	.00	

VITA

Robert Mark Brown was born in Macon, Georgia on 6 October 1954. He enlisted in the U.S. Army upon his graduation from high school in 1972 and received an appointment to the United States Military Academy at West Point, New York in 1973. He graduated with a Bachelor of Science Degree in 1977 and was commissioned a Second Lieutenant in Armor. He is currently serving in the U.S. Army in the grade of Major. His military education includes graduation from: the Armor Officer Basic and Advanced Courses, the Nuclear, Biological, and Chemical Warfare Officer's Course, the Management of Defense Acquisition Contracts Basic and Advanced Courses, the Materiel Acquisition Management Course, the Program Management Course of the Defense Systems Management College, the Combined Arms Staff and Services School of the Command and General Staff College, and he is a competitive selectee to attend the resident Command and General Staff College at Ft. Leavenworth, Kansas for the class entering in June 1990. In 1985 Major Brown was selected for and completed the U.S. Army's Training With Industry Program; training for one year as a mid-level manager in a major defense industry. During his Army career Major Brown has served in a wide range of command and staff positions in the United States and abroad. His assignments have included duty in the combat arms, twice as a commanding officer, and in the research, development, and materiel acquisition fields. His awards include the Meritorious Service Medal, the Joint Services Commendation Medal, the Army Commendation Medal, and the Army Achievement Medal. He has also published articles in several professional journals including: The Army Times, R,D,& A Bulletin, Armor Magazine, and Military Business

Review. Major Brown is a member of the Association of Graduates U.S.M.A., the Army Athletic Association, the Association of the U.S. Army, and the Armor Association. He is married to Major Mary K. Brown (formerly Cahill) of Pearl River, New York and has one daughter, Sarah, aged seven years.

Robert Mark Brown

signature