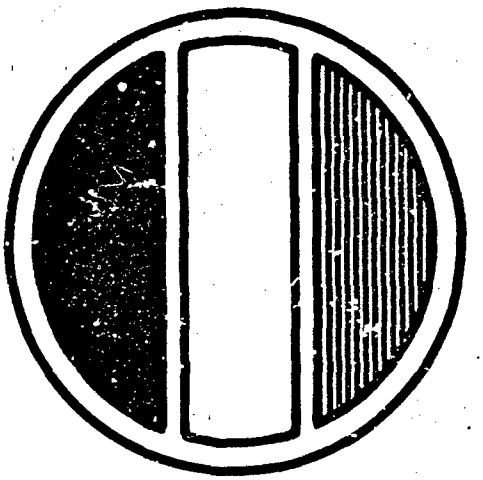
WHEELED VERSUS TRACKED VEHICLE STUDY

FINAL REPORT



ACN 070846

MARCH 1985

STUDIES AND ANALYSIS ACTIVITY
HEADQUARTERS
US ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23651-5000

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The Wheeled Versus Tracked Vehicle Study was performed by the HQ TRADOC Studies and Analysis Activity in response to a tasking from HQDA ODCSOPS (DAMO-FD). The purpose of the study was to conduct an analysis of the factors used in developing wheeled and tracked vehicle requirements and to lay the foundation for development of specific criteria upon which to base future vehicle requirements decisions. The study team made extensive use of existing data and examined the wheels versus tracks issue from the following perspectives: engineering and design, mobility, cost and foreign trends. The final report is presented in

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briefing format and contains the main briefing, answers to specific questions contained in the original tasking message and backup material supporting the conclusions contained in the main briefing.

UNITED STATES ARMY
TRAINING AND DOCTRINE COMMAND

WHEELED VERSUS TRACKED VEHICLE STUDY

ACN 070846

FINAL REPORT

31 March 1985

NOTICES

DISCLAIMER

The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other official documentation.

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ACKNOWLEDGEMENT

This study was initiated by HQDA ODCSOPS (DAMO-FD) and performed by the HQ TRADOC Studies and Analysis Activity (S&AA) at Fort Monroe, Virginia.

This report has been approved by the Commanding General, TRADOC.

The conclusions presented in this study are those of the Commanding General, TRADOC and are based on data analyzed by the HQ TRADOC S&AA. Support to the study effort was provided by the US Army Tank and Automotive Command (TACOM), the US Army Corps of Engineers' Waterways Experiment Station (WES), the US Army Foreign Science and Technology Center (FSTC) and the TRADOC Schools and Centers.

The TRADOC study team consisted of Mr. Kenneth L. Boyd (Study Coordinator), LTC Melvin C. Kadel, Mr. Herbert L. Russakoff and Mrs. Leslie E. Lampella.

Support from organizations external to TRADOC was provided by Mr. Cliff J. Nuttall, Jr., WES, CPT Robert F. Unger, WES, Mr. Lynn A. Martin, TACOM and Mr. James D. Nix, FSTC.

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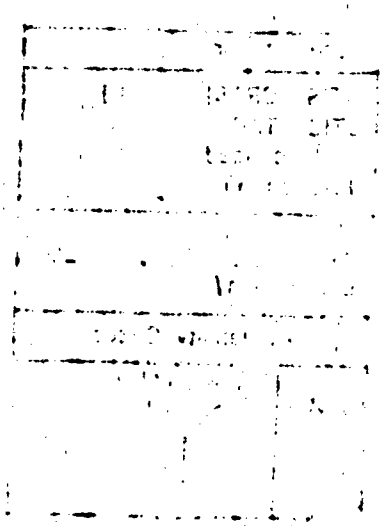

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ABSTRACT

The Wheeled Versus Tracked Vehicle Study was performed in response to a 15 May 84 tasking from HQDA ODCSOPS (DAMO-FD). The study provides an overview of the wheeled versus tracked vehicle subject area and answers several specific questions contained in the original tasking message. The study report is presented in briefing slide format and addresses the following subject areas: engineering and design, mobility, cost, perceptions of wheeled armored vehicles and foreign trends. The study team made extensive use of existing data. The report provides a general overview of the wheels versus tracks issue as it applies to military vehicle requirements.

EXECUTIVE SUMMARY

1. INTRODUCTION. The HQ TRADOC Studies and Analysis Activity (S&AA) conducted the Wheeled Versus Tracked Vehicle Study in the Jun 84 thru Mar 85 time frame. The study was performed in response to a HQDA ODCSOPS (DAMO-FD) tasking of 15 May 84.

2. Purpose.

a. To conduct an analysis of the factors used in developing wheeled and tracked vehicle operational requirements.

b. To lay a foundation for the development of specific criteria upon which to base future decisions regarding wheeled and tracked vehicles.

3. Discussion.

a. Background. On 15 May 84, HQDA ODCSOPS (DAMO-FD) tasked HQ TRADOC to conduct a Wheeled Versus Tracked Vehicle Study. The tasking resulted from questions raised by the Secretary of the Army in the Fall of 1983. In Jun 84, HQ TRADOC S&AA assumed proponency for the study and with assistance from the US Army Tank and Automotive Command (TACOM), the US Army Corps of Engineers' Waterways Experiment Station (WES), the US Army Foreign Science and Technology Center (FSTC) and the TRADOC Schools and Centers, conducted the study in the Jun 84 thru Mar 85 time frame.

b. Objectives.

(1) Identify the mission essential factors that should be considered when developing vehicle operational requirements.

(2) Identify the inherent engineering, mobility and cost differences between wheeled and tracked vehicles designed to perform similar missions.

(3) Identify the current uses, rationale and projected future uses of wheeled and tracked vehicles by allied, Warsaw Pact and major nonaligned nations.

(4) Lay the foundation for the development of quantifiable and defendable criteria to be used in the development of future wheeled and tracked vehicle requirements.

c. Assumptions. None.

d. Methodology. The general methodology employed in the study effort was to survey the professional literature to identify what was known about the wheeled versus tracked vehicle subject and consolidate the material into one coherent package. Generation of new data was held to a minimum because of the time available to perform the study and the fact that most of the relevant variables had already been exhaustively studied. The study was conducted in the following phases:

(1) Phase I. HQ TRADOC S&AA tasked the supporting organizations to conduct independent analyses of the wheeled versus tracked vehicle subject as it applied to their respective areas of expertise. These independent analyses were conducted in the Jul thru Nov 84 time frame.

(2) Phase II. HQ TRADOC S&AA integrated the results of the various supporting analyses into one coherent package, prepared the final briefing and published the final report. This effort was accomplished in the Nov 84 thru Mar 85 time frame.

e. Findings. Wheeled vehicles are superior for all vehicle mission roles that require either Tactical Support (15% off-road/65% on-road) or Tactical Standard (30% off-road/70% on-road) levels of operational mobility. For vehicles requiring a Tactical High (60% off-road/40% on-road) level of operational mobility, wheeled vehicles are competitive with tracked vehicles in cross-country performance up to around 10 tons gross vehicle weight (GVW). Above this level, wheeled vehicles must rely on higher levels of mechanical complexity and larger overall vehicle sizes in order to provide acceptable levels of cross-country mobility. These efforts tend to become ineffective at about the 20 ton GVW level where the size and mechanical complexity of high-mobility wheeled vehicles render them impractical for military use. Above the 10 ton GVW level, the mobility trade-offs imposed by the wheeled configuration seriously compromises its effectiveness as a direct fire combat platform. The cost advantage associated with the use of wheeled vehicles was found to lie principally in the operating and support (O&S) arena and is on the order of a 25 to 33 percent reduction in O&S costs. The general advantages associated with the use of wheeled vehicles tend to be in the cost and reliability arena and are purchased at the expense of operational utility. Tracked vehicles are intrinsically superior to wheeled vehicles in the cross-country environment, especially in the softer soils found in the temperate areas of the world. The review of foreign trends revealed that there is not a significant movement among major nations to embrace

wheeled armored vehicles for tactical use. France is the only major western nation that has made a substantial commitment to wheeled vehicles. Other countries that use wheeled armored vehicles tend to restrict their use to mission roles that complement the tracked force.

4. Conclusions.

a. Wheeled vehicles are preferred for all vehicle roles that require either Tactical Support or Tactical Standard levels of operational mobility.

b. For Tactical High levels of operational mobility:

(1) Up to 10 tons GVW, wheeled vehicles are preferred. The cross-country performance of high-mobility wheeled vehicles is competitive with tracks and significant O&S cost savings can be realized through the use of wheeled vehicles.

(2) In the 10 to 20 ton GVW range, tracked vehicles are preferred for all combat roles. Wheeled and tracked vehicles should be looked upon as competitors for support roles. The decision of whether a wheeled or tracked configuration is preferred for a particular support role is dependent upon what the role is and where it is going to be performed. This decision is best left to the cost effectiveness analysis process.

(3) Above 20 tons GVW, tracked vehicles are required. The size and mechanical complexity of high-mobility wheeled vehicles renders them impractical for military use.

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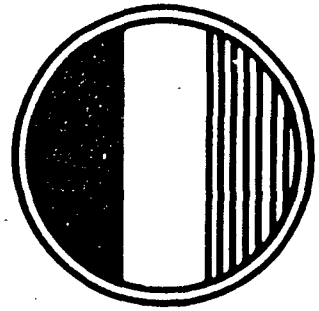
Chapter 1

Main Briefing

SLIDE 1 - TITLE

SELF-EXPLANATORY

WHEELED VERSUS TRACKED VEHICLE STUDY



MARCH 1985

STUDIES AND ANALYSIS ACTIVITY
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US ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23651-5000

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TRADOC

SLIDE 2 - SCOPE OF BRIEFING

SELF-EXPLANATORY

SCOPE OF BRIEFING

- BACKGROUND
- PURPOSE & METHODOLOGY
- TERMS OF REFERENCE
- SUPPORTING ANALYSES
  - •• FOREIGN TRENDS
  - •• MOBILITY ANALYSIS
  - •• ENGINEERING ANALYSIS
  - •• COST ANALYSIS
- STUDY CONCLUSIONS
- PERCEPTIONS OF WHEELED ARMORED VEHICLES
- FUTURE VEHICLE REQUIREMENTS

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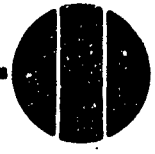
SLIDE 3 - BACKGROUND

The origin of the initiative that prompted this study effort was in September 83 with Secretary Marsh expressing a concern about the US Army's use of wheeled vehicles. In October 83, Mr Ambrose restated the question in a somewhat different form and various efforts were initiated within the Army staff to generate answers.

BACKGROUND

- 21 SEP 83, SA TO USA, "... THERE IS A QUESTION IN MY MIND WHETHER WE ARE FULLY EXPLOITING WHEELED VEHICLES. IT OCCURRED TO ME WE MIGHT DIRECT SOME STUDY OF THIS SITUATION EITHER IN THE ARMY OR OUTSIDE THE ARMY, OR BOTH"
- 5 OCT 83, USA RESTATED QUESTION AS: "... WHETHER WE HAVE A REASONABLE MIX (OF WHEELED AND TRACKED VEHICLES) WHEN COMPARED WITH WHATEVER RATIONALE AND MIX THE SOVIET UNION USES."



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SLIDE 4 - BACKGROUND (CONT)

For a variety of reasons, the efforts of the Army staff to provide conclusive answers to the questions raised by Mr Ambrose were not successful and in May 84, DAMO-FD tasked HQ TRADOC to conduct a Wheeled Versus Tracked Vehicle Study. HQ TRADOC initially tasked the Combined Arms Center to conduct the study but because of competing workload, CAC was not able to dedicate any resources to the project until the Fall of 84. In order to be responsive to HQDA, HQ TRADOC assumed proponency for the study and conducted it within the Studies and Analysis Activity at Fort Monroe.

BACKGROUND (CONT)

- HQDA (DAMO-FD) TASKING TO HQ TRADOC
  - •• 15 MAY 84, ODCSOPS (DAMO-FD) TASKS HQ TRADOC TO PERFORM A WHEELS VS TRACKS VEHICLE STUDY WITH TARGET DATE OF 31 JUL 84 FOR STUDY COMPLETION
  - •• JUN 84, HQ TRADOC (DCSCD) ASSUMES PROPONENCY FOR THE STUDY AND ESTABLISHES 31 OCT 84 AS THE TARGET DATE FOR STUDY COMPLETION
  - •• AUG 84, STUDY PLAN FORWARDED TO HQDA FOR APPROVAL
  - •• SEP 84, STUDY PLAN APPROVED BY HQDA

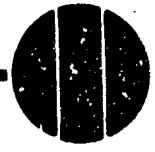
HEADQUARTERS TRADOC

SLIDE 5 - BACKGROUND (CONT)

The tasking HQ TRADOC received from HQDA (DAMO-FD) consisted of a general requirement to identify the advantages and disadvantages of wheeled and tracked vehicles over several performances, design, and cost parameters, ...

BACKGROUND (CONT)

- HQDA (DAMO-FD) TASKING TO HQ TRADOC (CONT)
  - •• IDENTIFY THE ADVANTAGES AND DISADVANTAGES OF WHEELED AND TRACKED VEHICLES IN THE FOLLOWING AREAS?
    - — MOBILITY
    - — TRAILER TOWING
    - — SHOCK AND VIBRATION
    - — TRANSPORTABILITY
    - — SURVIVABILITY
    - — PAYLOAD CAPACITY
    - — ONBOARD POWER GENERATION
    - — RELIABILITY, AVAILABILITY, AND MAINTAINABILITY
    - — RDT&E COSTS
    - — UNIT PRODUCTION COSTS
    - — LIFE CYCLE COSTS



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SLIDE 6 - BACKGROUND (CONT)

. . . and a series of specific questions. In the interest of time, answers to some of the specific questions will not be presented in this briefing. Answers are included in our backup material and will be included in the published version of the briefing.

BACKGROUND (CONT)

- HQDA (DAMO-FD) TASKING TO HQ TRADOC (CONT)
  - •• ARE THERE ANY VEHICLE MISSION ROLES THAT OUGHT TO BE EXCLUSIVELY ACCOMPLISHED BY WHEELED OR TRACKED VEHICLES?
  - •• IN PEACETIME COULD WHEELED VEHICLES BE SUBSTITUTED FOR TRACKED VEHICLES TO SAVE MAINTENANCE AND OTHER COSTS?
  - •• DO WE NEED TO PROVIDE SOME SHORT DISTANCE MOBILITY ENHANCEMENTS FOR WHEELED VEHICLES?
  - •• DOES THE HALF-TRACKED VEHICLE CONCEPT HAVE SUFFICIENT MERIT TO WARRANT RDT&E?
  - •• WHAT IS THE RELATIVE IMPORTANCE OF TERRAIN CONSIDERATIONS, IN COMPARISON TO OTHER FACTORS, FOR THE CBT, CS, AND CSS MISSION AREAS?

HEADQUARTERS
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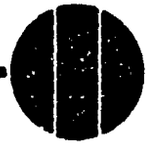
SLIDE 7 - BACKGROUND (CONT)

(Continuation of narrative on slide 6)

BACKGROUND (CONT)

- HQDA (DAMO-FD) TASKING TO HQ TRADOC
  - •• IS THE ARMY FULLY EXPLOITING THE ADVANTAGES OF WHEELED VEHICLES?
  - •• WHAT ARE THE CAPABILITIES AND LIMITATIONS OF WHEELED AND TRACKED VEHICLES WHICH THE ARMY CAN USE AS EVALUATION CRITERIA FOR DETERMINING WHICH CATEGORY OF VEHICLE IS PREFERABLE FOR EACH MISSION AREA AND FUNCTIONAL APPLICATION?



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SLIDE 8 - PURPOSE

SELF-EXPLANATORY

PURPOSE

- CONDUCT AN ANALYSIS OF THE FACTORS USED IN DEVELOPING WHEELED AND TRACKED VEHICLE OPERATIONAL REQUIREMENTS
- LAY THE FOUNDATION FOR DEVELOPMENT OF SPECIFIC CRITERIA UPON WHICH TO BASE FUTURE DECISIONS REGARDING WHEELED AND TRACKED VEHICLES

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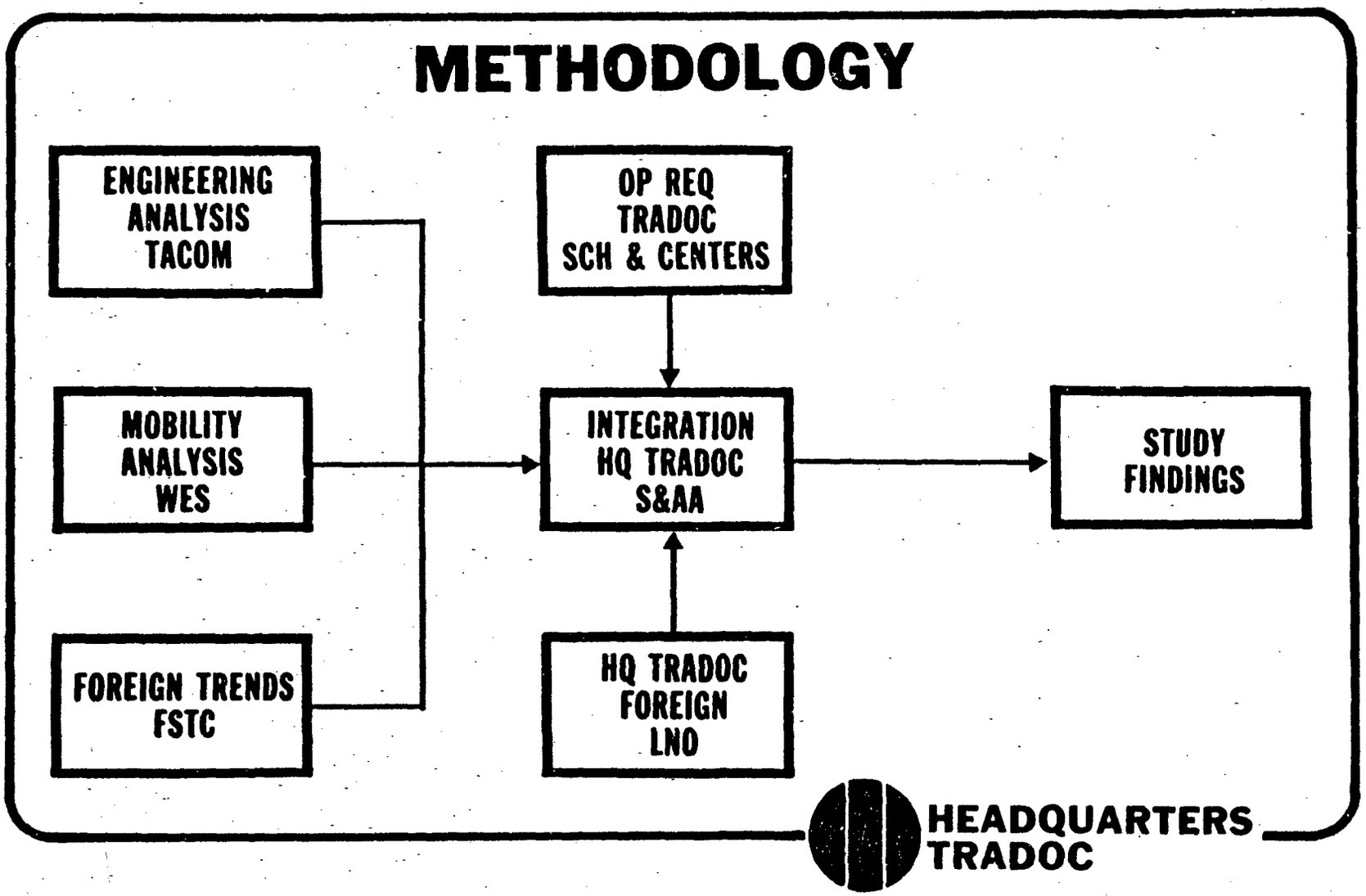
SLIDE 9 - METHODOLOGY

The study was attacked on five fronts. The Army Material Command's Tank and Automotive Command (TACOM) conducted an analysis of the various engineering parameters of interest. The Army Corps of Engineer's Waterways Experiment Station (WES) under contract to HQ TRADOC contributed the mobility analysis. The Foreign Science and Technology Center (FSTC) developed the foreign trends in the use of wheeled and tracked vehicles. The TRADOC Schools and Centers examined vehicle operational requirements. In addition, we contacted the French, British, West German, Canadian and Dutch Liaison Officers at Fort Monroe to solicit any additional input that would be representative of the foreign experience with wheeled combat vehicles.


METHODOLOGY
ENGINEERING ANALYSIS TACOM
OP REQ TRADOC SCH & CENTERS
MOBILITY ANALYSIS WES
INTEGRATION HQ TRADOC S&AA
STUDY FINDINGS
FOREIGN TRENDS FSTC
HQ TRADOC FOREIGN LNO
HEADQUARTERS TRADOC

SLIDE 10 - IS THE ARMY FULLY EXPLOITING THE ADVANTAGES OF WHEELED VEHICLES

This is the fundamental question that prompted the analysis. The key word in this question is "advantages" which presupposes that there are some intrinsic advantages associated with the use of wheeled vehicles, or more specifically, wheeled armored vehicles.

IS THE ARMY FULLY EXPLOITING THE ADVANTAGES OF WHEELED VEHICLES?

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SLIDE 11 - PERCEPTIONS OF WHEELED ARMORED VEHICLES

In reviewing the articles written by the various proponents for wheeled armored vehicles, three areas were identified where the advocates of wheeled armor argue that untapped benefits are waiting to be realized. We will be exploring these three areas during the briefing and come back to them at the end during our formal conclusions.

PERCEPTIONS OF WHEELED ARMORED VEHICLES

- ACCEPTABLE PERFORMANCE
- LOWER COST
- EXPANDED FOREIGN USE

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SLIDE 12 - TERMS OF REFERENCE

During the briefing, we will be referring to a few common terms and in the interest of clarity, we will define them before we begin.

TERMS OF REFERENCE

HEADQUARTERS
TRADOC

SLIDE 13 - TERMS OF REFERENCE

Depicted here are the TRADOC standard definitions of vehicle operational mobility contained in the US Army Wheeled Vehicle Master Plan. The terms are used when the mobility requirement for a projected vehicle mission role is defined in the projected vehicle's Organization and Operation Plan. Tactical Support Mobility is the least demanding level of off-road mobility. It would be found in normal road vehicles or tractor semi-trailer combinations. The interim level, Tactical Standard Mobility, is encountered in a traditional military logistics vehicle, for example, a 2 1/2 or 5 ton truck. The new 10 Ton Heavy Expanded Mobility Tactical Truck (HEMTT) goes somewhat beyond Tactical Support Mobility in its operational requirement. However, it is not a Tactical High Mobility vehicle. Tactical High Mobility is the most demanding level of operational mobility. General purpose tracked vehicles are Tactical High Mobility vehicles. Wheeled vehicles in this category are the Gamma-Goat, the GOER, the HMMWV and the Marine Corps' Light Armored Vehicle, the LAV.

More demanding levels of vehicle mobility may be defined, for example an over the snow capability, but they are for specialized vehicles, justified on a case-by-case basis. For the purpose of this briefing, we will restrict ourselves to these three mobility levels which encompass all general purpose vehicles.

TERMS OF REFERENCE

- **TRADOC DEFINITIONS OF VEHICLE OPERATIONAL MOBILITY**
  - •• TACTICAL SUPPORT MOBILITY (TRACTOR/SEMI-TRAILERS, HET, ETC.)
    - 15% OFF-ROAD
    - 85% ON-ROAD
  - •• TACTICAL STANDARD MOBILITY (2 1/2 TON & 5 TON TRUCKS, ETC.)
    - 30% OFF-ROAD
    - 70% ON-ROAD
  - •• TACTICAL HIGH MOBILITY (TRACKED VEHICLES, HMMWV, GOER, ETC.)
    - 60% OFF-ROAD
    - 40% ON-ROAD

HEADQUARTERS
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SLIDE 14 - TERMS OF REFERENCE (CONT)

Another term we will be referring to during the briefing is the Vehicle Cone Index or VCI. The VCI is a characteristic of the vehicle and is normally shown with a subscript. The VCI represents the minimum ground strength, on the Rating Cone Index (RCI) scale, required to support the subscripted number of passes by the vehicle. For example a VCI sub one, would be one vehicle pass whereas a VCI sub 50 would be 50 vehicle passes. For the purposes of our analysis, we will be referring to a single vehicle pass and will show VCI without the one subscript. VCI_1 is an excellent first order measure of overall vehicle mobility. The RCI scale, that the VCI_1 corresponds to, is a measured characteristic of soil strength and is defined for a given area of ground at a given point in time.

Depicted on the viewgraph are the typical ranges of VCI_1 for wheeled and tracked vehicles. It is important to note that on average, wheeled vehicles carry VCI_1 ratings 10 to 15 points higher than tracked vehicles and the area of overlap between the two vehicle configurations is relatively small.

Backup Slide - 1

TERMS OF REFERENCE (CONT)

- VEHICLE CONE INDEX (VCI)
  - •• CHARACTERISTIC OF THE VEHICLE
  - •• GOOD FIRST ORDER MEASURE OF VEHICLE SOFT-SOIL MOBILITY
  - •• THE LOWER THE VCI THE BETTER
    - AVERAGE TRACKED VEHICLES RANGE FROM 10 TO 25
    - AVERAGE WHEELED VEHICLES RANGE FROM 20 TO 50
  - •• A VCI OF 25 WILL GIVE A VEHICLE ABOUT 80% TERRAIN MOBILITY IN TEMPERATE AREAS UNDER WET SOIL CONDITIONS

HEADQUARTERS
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SLIDE 15 - FOREIGN TRENDS

When TRADOC originally received the study tasking, GEN Richardson requested us to examine what West Germany, the United Kingdom, France and Israel were doing with their military vehicle fleets and include a discussion of their general trends in the overall study. We expanded his guidance to include a look at all major allied and Warsaw Pact nations.

FOREIGN TRENDS

HEADQUARTERS
TRADOC

SLIDE 16 - FOREIGN TRENDS

We found the primary area where a divergence exists in the vehicle fleet philosophy of the US and major foreign governments is in the use of wheeled armored vehicles. With the exception of the Marine Corps' Light Armored Vehicle, the US reserves the armored vehicle role for tracks. This is also true for some foreign governments, for example, Belgium, Italy and Japan. However, most foreign governments make use of wheeled armored vehicles either in light motorized forces or to a limited degree in the support elements of heavy forces. The Warsaw Pact countries have made the heaviest commitment to wheeled armored with France being the only West European country to make a similar commitment. West Germany and the United Kingdom both use wheeled armor but restrict their roles to scouts, support vehicles and internal security. Israel limits wheeled armor to an internal security role. Canada is expanding its wheeled armored vehicle fleet but is currently restricting its use to training and as a means of providing armored protection for vehicle mission roles previously supported by trucks. The Dutch are moving away from the use of wheeled armor and are replacing their fleet of wheeled APCs with tracks.

In general, for the countries we examined, wheeled armored vehicles are not looked upon as replacements for tracked vehicles. The tracked vehicle has been and continues to be the automotive configuration of choice for the combat elements of heavy forces. Wheeled armored vehicles are used to complement the tracked force and to provide armored protection for vehicle roles that would otherwise be supported by trucks.

Backup Slides - 2, 3, 4, 5, 6, 7, 8, 9 & 10

FOREIGN TRENDS

- THE PRIMARY DIVERGENCE BETWEEN THE US AND FOREIGN GOVERNMENTS IS IN THE USE OF WHEELED ARMORED VEHICLES
- LIGHT MOTORIZED FORCES
  - •• SCOUTS
  - •• ARMORED PERSONNEL CARRIERS
  - •• UTILITY CS AND CSS VEHICLES
- HEAVY FORCES
  - •• UTILITY CS AND CSS VEHICLES

HEADQUARTERS
TRADOC

SLIDE 17 - FOREIGN TRENDS (CONT) - SOVIET UNION - ORDER OF BATTLE

Slide #17 contained in Appendix C (classified)

SLIDE #17 CONTAINED IN APPENDIX C (CLASSIFIED)

HEADQUARTERS
TRADOC

SLIDE 18 - FOREIGN TRENDS (CONT) - 8TH GUARDS ARMY

Slide #18 contained in Appendix C (classified)

SLIDE #18 CONTAINED IN APPENDIX C (CLASSIFIED)

HEADQUARTERS
TRADOC

SLIDE 19 - FOREIGN TRENDS (CONT) - BOTTOM LINE

With the exception of France, the generally observed trend in the western democracies is that wheeled armored vehicles are being introduced to provide limited armor protection to vehicle mission roles that historically were supported by trucks. Wheeled armored vehicles maintain the high road speed advantage of trucks while providing armor protection to the occupants and cargo.

Since the introduction of the BMP in 1967, the Soviet Union has established a very clear trend of upgrading its motorized divisions by replacing wheeled armored vehicles with tracks.

The non-Soviet Warsaw Pact countries appear to be following the Soviet example and are upgrading their motorized forces by introducing more tracked vehicles.

The third world is the primary area where the use of wheeled armored vehicles is expanding. The threat faced by third world countries is quite limited when compared with the threat faced by a major military power. Third world countries are primarily concerned with internal security and presenting a credible deterrent to their neighbors. Wheeled armored vehicles are well suited to these limited mission roles and lesser threat. Additionally, third world countries normally have very limited defense budgets and the cost savings associated with the use of wheeled armor is very important. We will be examining the wheeled armored vehicle cost savings later in the briefing.

BOTTOM LINE -- FOREIGN TRENDS

- **WESTERN COUNTRIES**
  - —WITH THE EXCEPTION OF FRANCE, COUNTRIES THAT USE WHEELED ARMORED VEHICLES LOOK UPON THEM AS A REPLACEMENT FOR THIN-SKINNED VEHICLES
- **SOVIET UNION**
  - —SINCE THE 1960's, HAVE BEEN UPGRADING MOTORIZED FORCES BY INTRODUCING MORE TRACKED VEHICLES
- **NON-SOVIET WARSAW PACT**
  - —APPEAR TO BE FOLLOWING THE SOVIET EXAMPLE
- **THIRD WORLD**
  - —EXTENSIVE USER OF WHEELED ARMOR
    - -LIMITED THREAT
    - -INTERNAL SECURITY
    - -ECONOMIC CONSIDERATIONS

HEADQUARTERS
TRADOC

SLIDE 20 - MOBILITY ANALYSIS

Given we have identified wheeled armored vehicles as the area of differing vehicle fleet philosophy, let us look specifically at the weight ranges where wheeled armored vehicles are feasible and the general mobility trade-offs required for their use.

MOBILITY ANALYSIS

HEADQUARTERS
TRADOC

SLIDE 21 - MOBILITY ANALYSIS - SOFT-SOIL MOBILITY

In soft-soil mobility, we find high-mobility wheeled vehicles are competitive with tracked vehicles up to gross vehicle weights (GVW) of approximately 10 tons. Above this level, it becomes necessary to resort to higher levels of mechanical complexity or larger wheel sizes in order to maintain wheeled vehicles at a competitive level of soft-soil mobility. At approximately 20 tons, the size and complexity of high-mobility wheeled vehicles render them impractical for military use.

In looking at what has been built around the world, we see the greatest preponderance of wheeled armored vehicle designs fall within the 8 to 18 ton GVW range. Eight tons GVW is about the lower limit for a general purpose wheeled armored vehicle. The few designs below this level tend to be small specialized vehicles designed to support specific mission requirements. A few vehicles have been built above the 18 ton GVW level. However, these tend to be special purpose vehicles designed to do specific missions.

Backup Slide - 11

MOBILITY ANALYSIS

- **SOFT-SOIL MOBILITY**
  - •• UP TO 10 TONS GVW -- WELL DESIGNED HIGH MOBILITY WHEELED VEHICLES (E.G., JEEP, HMMWV, ETC.) ARE COMPETITIVE WITH AVERAGE TRACKED VEHICLES
  - •• ABOVE 10 TONS GVW -- WHEELED VEHICLES BECOME LARGER AND MORE COMPLEX
  - •• ABOVE 20 TONS GVW -- THE SIZE AND COMPLEXITY OF HIGH MOBILITY WHEELED VEHICLES MAKES THEM IMPRACTICAL FOR MILITARY USE

HEADQUARTERS
TRADOC

SLIDE 22 - MOBILITY ANALYSIS (CONT) - SAND

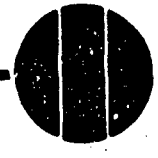
On coarse hard packed sand, there is essentially no difference in the mobility of wheeled or tracked vehicles. These surfaces provide excellent mobility for either vehicle configuration.

As the sand becomes finer, wheeled vehicles begin to experience serious mobility problems and it is necessary to resort to various mobility enhancers in order to maintain their mobility.

Backup Slide - 12

MOBILITY ANALYSIS (CONT)

- SAND
  - •• FIRM (HARD PACKED)
    - WHEELED AND TRACKED VEHICLES ARE COMPARABLE
  - •• SOFT (SHIFTING/BLOWING)
    - WHEELED VEHICLES NOT COMPETITIVE WITH TRACKED VEHICLES
    - WHEELED VEHICLE MOBILITY ENHANCERS REQUIRED
      - -- SPECIAL TIRES
      - -- CENTRAL TIRE INFLATION SYSTEMS
      - -- EXPEDIENT SURFACING MATERIALS



HEADQUARTERS
TRADOC

SLIDE 23 - MOBILITY ANALYSIS (CONT) - SNOW

In deep snow, it is necessary to have an over-the-snow vehicle that has a very low ground pressure. This is a mission profile that is almost totally reserved for special purpose tracked vehicles. It is possible to build a wheeled over-the-snow vehicle but its size tends to make it impractical for military use. The Swedish BV206 is an excellent example of a tracked over-the-snow vehicle that also has excellent mobility in non-snow environments.

In shallow snow, both wheeled and tracked vehicles go through the snow, packing it down and pushing it aside as they go. Tracked vehicles can maintain mobility in depths up to three feet. Wheeled vehicles are mobile in shallow snow up to around 1/3 of their tire diameter. This tolerance can be increased 10-20 percent by the use of tire chains. An interesting anomaly in shallow snow mobility is that wheeled vehicles with very high VCI ratings tend to be more mobile that vehicles with low VCI ratings. The vehicle with the higher VCI rating will pack the snow down and move on through it whereas the vehicle with the lower VCI rating will not be able to compress the snow enough to gain traction. Shallow snow is the one area where with a wheeled vehicle, the higher the VCI rating, the better.

MOBILITY ANALYSIS (CONT)

- SNOW
  - •• OVER THE SNOW
    - SIZE OF WHEELED VEHICLES MAKES THEM IMPRACTICAL FOR MILITARY USE
  - •• THROUGH THE SNOW
    - TRACKED VEHICLES
      - -- MOBILE IN DEPTHS UP TO 3 FT
    - WHEELED VEHICLES
      - -- COMPETITIVE WITH TRACKED VEHICLES IN DEPTHS UP TO 1/3 OF THE TIRE DIAMETER
      - -- TIRE CHAINS PROVIDE 10-20 PERCENT INCREASE IN DEPTH TOLLERANCE
      - -- HIGHER GROUND PRESSURES (VCI> 40) ENHANCE MOBILITY

HEADQUARTERS
TRADOC

SLIDE 24 - MOBILITY ANALYSIS (CONT) - OBSTACLE NEGOTIATION

For vertical walls and linear features, such as dikes in rice fields or rubble from demolished buildings, wheeled vehicles are competitive with tracked vehicles up to the height of the wheeled vehicles vertical ground clearance. Above this height, problems are encountered with the bottom of the wheeled vehicle grounding on the obstruction. Tracked vehicles do not have this problem because of their self-bridging capability arising from the continuous track on each side of the vehicle. Additionally, tracked vehicles offer superior soft-soil mobility to propel the vehicle over the obstacle when part of the tracks are off the ground.

For negotiating gaps, ditches, and fording, tracked vehicles are inherently superior, especially in the soft/wet soils that are normally encountered on the sides and bottom of a gap or ditch. Additionally, tracked vehicles do not have the belly hang-up problem that wheeled vehicles incur during ingress/egress.

In swimming situations, the superior gap crossing capability of a tracked vehicle makes it the superior platform during ingress/egress. In actual swimming capability, the two classes of vehicles are comparable.

Backup Slides - 13, 14, 15 & 16

MOBILITY ANALYSIS (CONT)

- **OBSTACLE NEGOTIATION**
  - •• VERTICAL WALLS AND LINEAR FEATURES
    - WHEELED VEHICLES ARE COMPETITIVE UP TO THE HEIGHT OF THEIR VERTICAL GROUND CLEARANCE
    - ABOVE THIS HEIGHT, TRACKED VEHICLES ARE SUPERIOR DUE TO BETTER SOFT-SOIL AND SELF-BRIDGING CAPABILITY
  - •• GAPS, DITCHES AND FORDING
    - TRACKED VEHICLES ARE SUPERIOR DUE TO BETTER SOFT-SOIL MOBILITY AND SELF-BRIDGING CAPABILITY
  - •• SWIMMING
    - TRACKED VEHICLES ARE SUPERIOR DURING INGRESS/EGRESS
    - WHEELED AND TRACKED VEHICLES ARE COMPARABLE IN ACTUAL SWIMMING CAPABILITY

HEADQUARTERS TRADOC

SLIDE 25 - MOBILITY ANALYSIS (CONT) - AGILITY AND MANEUVERABILITY

We examined these three major factors that contribute to overall vehicle agility.

In the 500 meter dash, we found that the primary discriminator is power to weight ratio rather than automotive configuration. On firmly packed soil, wheeled and tracked vehicles with similar power to weight ratios will achieve similar dash times. As the soils get softer and wetter, the superior soft/wet soil mobility of a tracked vehicle will give it a considerable advantage in dash times. The same would be true for operations in soft sand.

In stopping distances, the differences between the two vehicle configurations are minor but we see a clear trend that up to 25 mph, wheeled vehicles have a minor advantage which flips over to tracks above 25 mph. It appears that the mechanically different method of applying the brakes is the major factor contributing to this difference.

In the slalom, tracked vehicles are marginally superior due to their skid steering ability to make tighter turns. Though, it should be noted that as speeds go up, a tracked vehicle places greater demands on the driver in a slalom situation. Wheeled vehicles will normally just plow forward in the dirt when they are turned too fast whereas a tracked vehicle may turn over.

Which brings us to maneuverability. The skid-steer capability of the tracked vehicle makes it the superior platform, especially for operations in built-up areas or in terrain where a significant number of obstacles are encountered. Wheeled vehicles can be designed with skid steering, but in general, they require a greater soil strength differential in turning situations than would a comparable tracked vehicle. The French AMX 10 RAC is an example of a skid-steer wheeled combat vehicle. It is essentially a wheeled version of the tracked AMX 10.

Backup Slide - 17

MOBILITY ANALYSIS (CONT)

- **AGILITY**
  - •• 500 METER DASH
    - ON FIRMLY PACKED SOIL, WHEELED AND TRACKED VEHICLES WITH EQUAL POWER TO WEIGHT RATIOS ARE COMPARABLE
    - TRACKED VEHICLES ARE SUPERIOR IN SOFT/WET SOILS AND SAND
  - •• STOPPING DISTANCES
    - UP TO 25 MPH, WHEELED VEHICLES ARE MARGINALLY SUPERIOR
    - ABOVE 25 MPH, TRACKED VEHICLES ARE MARGINALLY SUPERIOR
  - •• SLALOM
    - TRACKED VEHICLES ARE MARGINALLY SUPERIOR
- **MANEUVERABILITY**
  - •• TRACKED VEHICLES ARE SUPERIOR DUE TO THEIR ABILITY TO PIVOT ON ONE TRACK

HEADQUARTERS
TRADOC

SLIDE 26 - MOBILITY ANALYSIS (CONT) - SHOCK AND VIBRATION & AVERAGE SPEEDS

The on-road environment is the most hostile environment for a tracked vehicle. As each track pad impacts the road surface, a vibration is induced into the chassis that is proportional to the road speed. This problem is unique to tracked vehicles. It contributes to crew fatigue and generates unique equipment isolation problems for onboard equipment.

In the off-road environment, wheeled and tracked vehicles are comparable. The track pad vibration problem does not occur on softer off-road surfaces. WES studies have found that wheeled and tracked vehicles are comparable in the average speeds that their drivers will maintain over varying degrees of surface roughness while subjecting themselves to 2.5g vertical accelerations and 6 watt vibration levels over extended periods.

Wheeled and tracked vehicles present designers with different vibration isolation problems, but the problems are not difficult to overcome and the equipment isolation mounts are not significant cost drivers.

In looking at average speeds obtainable while performing a vehicle mission, we found that wheeled vehicles have an advantage on-road and tracked vehicles have an advantage off-road. The wheeled vehicle's on-road speed advantage only results in a time savings of less than two minutes in a typical 10km mission that would be found in a brigade's tactical area of operations. Whereas in the off-road environment, the differences in travel time between a wheeled and tracked vehicle can be quite significant. It is primarily in self-deployment situations where the on-road speed advantage of wheeled vehicles is most important.

Backup Slides - 18 & 19



MOBILITY ANALYSIS (CONT)

- SHOCK AND VIBRATION
  - •• ON-ROAD
    - — WHEELED VEHICLES ARE SUPERIOR
    - — MOST HOSTILE ENVIRONMENT FOR TRACKED VEHICLES
  - •• OFF-ROAD
    - — WHEELED AND TRACKED VEHICLES ARE COMPARABLE
- AVERAGE SPEEDS
  - •• ON-ROAD
    - — WHEELED VEHICLES ARE SUPERIOR
    - — TIME DIFFERENCES ARE LESS THAN 2 MIN FOR 10 KM MISSION
  - •• OFF-ROAD (CROSS COUNTRY)
    - — TRACKED VEHICLES ARE SUPERIOR
    - — TIME DIFFERENCES CAN BE SIGNIFICANT FOR A 10 KM MISSION

HEADQUARTERS
TRADOC

SLIDE 27 - MOBILITY ANALYSIS (CONT) - MEAN PERCENT TERRAIN MOBILITY

Here we have depicted the average percent terrain mobility for a group of eight high mobility wheeled combat vehicles and nine tracked combat vehicles. These results are from a special run of the Army Mobility Model that WES did in support of this study. We see that on average tracked vehicle are mobile over 5 to 15 percent more of the terrain. It should be emphasized that the set of wheeled vehicles used in this analysis represents a group of state-of-the-art high-mobility combat vehicle designs. The Marine Corps' LAV was the least mobile vehicle in the group. Consequently, one should look at this comparison as a best case situation for wheels. If more average wheeled vehicles were used, the mobility differences between the two vehicle configurations would be more pronounced.

Backup Slides - 20 & 21

COMBAT VEHICLES
MEAN PERCENT TERRAIN MOBILITY

	WHEELED	TRACKED
LAUTERBACH, FRG		
DRY (8 MO)	91%	95%
WET (2 MO)	80%	90%
SNOW (2 MO)	79%	84%
MAFRAG, JORDAN		
DRY (11 MO)	93%	99%
WET (1 MO)	93%	98%
SAND	83%	99%

AVERAGE PERFORMANCE

- EIGHT WHEELED COMBAT VEHICLES -- MEAN VCI=24.5
- NINE TRACKED COMBAT VEHICLES -- MEAN VCI=17.3

HEADQUARTERS
TRADOC

SLIDE 28 - MOBILITY ANALYSIS (CONT) - MISSION PERFORMANCE TIMES

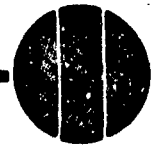
WES expanded the previous analysis to come up with what we are calling a mission performance time. It integrates road speed, gap crossing and cross-country speed to estimate the percent off-road travel involved where wheeled vehicles are still competitive with tracked vehicles in the time required to perform a 10km mission. The results show that in Lauterbach, wheeled vehicles are competitive as long as the mission requires no more than 50% off-road travel in the dry season or 30% off-road travel in the wet season. In Mafraq, the amount of permissible off-road travel increases to around 70%.

Recall that our definition of Tactical High Mobility was 60% off-road. Given that criteria, we see that wheeled vehicles are competitive with tracked vehicles in the arid Mafraq environment but not in the temperate Lauterbach environment. This is especially true during the wet season.

Backup Slides - 22, 23, 24 & 25

MOBILITY ANALYSIS (CONT)

- MISSION PERFORMANCE TIMES
  - •• INTEGRATE THE EFFECTS OF CROSS COUNTRY SPEED, ROAD SPEED, AND GAP CROSSING CAPABILITIES TO ARRIVE AT AN ESTIMATE OF THE AMOUNT OF TIME REQUIRED TO PERFORM A 10 KM VEHICLE MISSION
  - •• RESULTS
    - LAUTERBACH, FRG
      - -- DRY SEASON - WHEELS COMPETITIVE WITH TRACKS UP TO 50 PERCENT OFF-ROAD
      - -- WET SEASON - WHEELS COMPETITIVE WITH TRACKS UP TO 30 PERCENT OFF-ROAD
    - MAFRAQ, JORDAN
      - -- DRY SEASON - WHEELS COMPETITIVE WITH TRACKS UP TC 70 PERCENT OFF-ROAD
      - -- WET SEASON - WHEELS COMPETITIVE WITH TRACKS UP TO 60 PERCENT OFF-ROAD



HEADQUARTERS
TRADOC

SLIDE 29 - BOTTOM LINE - MOBILITY ANALYSIS

The bottom line of the mobility analysis is that for either Tactical Support or Tactical Standard levels of operational mobility, the wheeled vehicle is competitive with the tracked vehicle in mission performance time and offers a lower level of terrain induced vibration for on-road operations. These vehicle mission roles are performed primarily on improved surfaces and the wheeled vehicle is the superior platform in this environment.

For Tactical High Mobility vehicle roles. Up to around 10 tons gross vehicle weight (GVW), wheeled vehicles are competitive with tracked vehicles. Above 20 tons GVW, the size and complexity of high-mobility wheeled vehicles makes them impractical for military use. In the 10-20 ton GVW range, wheeled vehicles compete with track vehicles but become progressively less competitive as the GVW increases from 10 to 20 tons. Additionally, the tracked configuration offers some intrinsic operational advantages that are not found in wheeled vehicles.

BOTTOM LINE -- MOBILITY ANALYSIS

- TACTICAL SUPPORT MOBILITY -- WHEELED VEHICLES SUPERIOR
- TACTICAL STANDARD MOBILITY -- WHEELED VEHICLES SUPERIOR
- TACTICAL HIGH MOBILITY -- WHEELS AND TRACKS
  - •• BELOW 10 TONS -- WHEELED VEHICLES COMPETITIVE
  - •• ABOVE 20 TONS -- TRACKED VEHICLES REQUIRED
  - •• 10 TO 20 TONS
    - TRACKS MOBILE OVER 5 TO 15 PERCENT MORE TERRAIN
    - TRACKS ARE MORE MANEUVERABLE
    - TRACKS ARE BETTER AT OBSTACLE NEGOTIATION

HEADQUARTERS
TRADOC

SLIDE 30 - ENGINEERING ANALYSIS

To carry the analysis further, we examined several engineering parameters to identify the intrinsic differences between wheeled and tracked vehicles. We restricted this portion of the analysis to the 10 to 20 ton GVW class.

ENGINEERING ANALYSIS

HEADQUARTERS
TRADOC

SLIDE 31 - ENGINEERING ANALYSIS - VEHICLE VOLUME AND PAYLOAD VOLUME

By design, tracked vehicles are more compact. This results from a combination of reduced suspension clearance, wheel turning clearance, and the absence of the multiple transfer cases and drive shafts that are found in wheeled vehicles. A VCI of 20 will give a vehicle about 90% terrain mobility in a temperate area during the wet season. In order to achieve a VCI of 20 in a 10-20 ton wheeled vehicle, it will require using six times more volume for drive train and suspension components than in a comparable tracked vehicle. This translates to a overall increase in vehicle size from 16 to 28 percent if the same interior volume is retained. Wheeled armored vehicle designers normally trade-off VCI in order to keep the overall vehicle volume as small as possible. The Marine Corps LAV is an excellent example where a VCI of 31 was accepted in order to keep the vehicle small enough for C-130 air transport. If a VCI of 25 had been required for the LAV, it would have been necessary for the vehicle to be 23 inches longer, 10 inches wider, and 10 inches higher to accommodate the larger tires. This would have made the vehicle too big for C-130 air transport.

The net result of the tracked vehicle's drive train packaging efficiency is that for a given overall vehicle size, a tracked vehicle will offer greater payload cube or lower VCI.

Backup Slides - 26, 27 & 28

ENGINEERING ANALYSIS

- VEHICLE VOLUME
  - •• TRACKED VEHICLES ARE MORE COMPACT
  - •• FOR COMPARABLE VEHICLES WITH A VCI OF 20
    - — 10 TON GVW CLASS -- WHEELED VEHICLE 16% LARGER
    - — 15 TON GVW CLASS -- WHEELED VEHICLE 28% LARGER
    - — 20 TON GVW CLASS -- WHEELED VEHICLE 27% LARGER
- PAYLOAD VOLUME
  - •• FOR A GIVEN SIZE VEHICLE, A TRACKED VEHICLE WILL OFFER GREATER PAYLOAD CUBE

HEADQUARTERS
TRADOC

SLIDE 32 - ENGINEERING ANALYSIS - TRANSPORTABILITY

We looked at transportability by both surface and air and our findings are summarized on this chart. The one key feature in surface transportability is the ability of wheeled vehicles to self-deploy over the road network within a theater. This is a major advantage of wheeled vehicles and is a factor cited by the French in their decision to equip their contingency force with wheeled armor. If the vehicles are to be carried by surface modes, such as trucks, rail cars or ships, wheeled and tracked vehicles present similar handling problems.

In air transport, there is a restriction for C-141B aircraft that limits the maximum single axle load of a wheeled vehicle to 10,000 lbs. This results in a theoretical upper weight limit of 15 tons for a 6X6 or 20 tons for an 8X8 wheeled vehicle. Since the actual vehicle weight distribution is not uniform, the real GVW limit will be somewhat less than the 15 and 20 ton values shown. It is possible to overcome this restriction through the use of shoring on the floor of the aircraft but this entails some special handling problems when loading the vehicle.

Dimensionally, the C-130 is our most restrictive aircraft for the equipment designer. With ground-up new designs, it is possible to design either wheeled or tracked vehicles for C-130 air transport. The inherently more compact automotive configuration of a tracked vehicle makes the equipment designers job easier and fewer mobility trade-offs will have to be made in order to achieve C-130 air transportability.

ENGINEERING ANALYSIS (CONT)

- TRANSPORTABILITY
  - •• SURFACE
    - — WHEELED VEHICLES ARE CAPABLE OF INTRA-THEATER SELF-DEPLOYMENT
    - — WHEN TRANSPORTED, WHEELED AND TRACKED VEHICLES PRESENT SIMILAR TRANSPORTATION PROBLEMS
  - •• AIR
    - — EASIER TO DESIGN TRACKED VEHICLES FOR AIR TRANSPORT
    - — 5 TON AXLE LOAD RESTRICTION IN C-141B
      - -- 15 TONS MAXIMUM SHIPPING WEIGHT FOR 6 X 6 WHEELED VEHICLE
      - -- 20 TONS MAXIMUM SHIPPING WEIGHT FOR 8 X 8 WHEELED VEHICLE
      - -- RESTRICTION CAN BE OVERCOME BY USING SHORING

HEADQUARTERS
TRADOC

SLIDE 33 - ENGINEERING ANALYSIS (CONT) SURVIVABILITY/VULNERABILITY

With a 10 to 20 ton GVW light armored vehicle, it is possible to achieve ballistic protection against artillery fragments and 7.62mm AP light infantry weapons. As the gross vehicle weight approaches 20 tons, one begins to achieve protection against 14.5mm AP rounds. It is possible to achieve only limited protection against 30mm AP or chemical energy type weapons in this weight class of vehicle.

Given that a wheeled and tracked vehicle carry equivalent armor, they will be comparable in their vulnerability to artillery fragments and small arms. The tire deflation problem of wheeled armored vehicles can be offset by a run-flat insert or ideally, a combination of a run-flat insert, self-sealing tires and a central tire inflation system. With these measures, if a wheeled vehicle's tires are punctured, it will still be able to move around the battlefield, though somewhat diminished in performance. A question exists on the probability of a wheeled vehicle suffering a mobility kill from a small air scatterable mine. A small mine would destroy a tire, but it is unknown if the collateral effects of the detonation would damage the vehicle's steering to the point that the vehicle would become inoperable. More work needs to be done in this area.

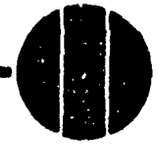
Thermal and radar signatures are comparable for the two vehicle configurations.

Vehicle silhouette will be marginally smaller for a tracked vehicle but the difference may be below the detection threshold.

Acoustic signatures are presently significantly lower for wheeled vehicles but this is as much a function of the tracked vehicle's unmuffled exhaust as it is track noise. We were not able to identify any tests where muffled track vehicles were compared with muffled wheeled vehicles.

ENGINEERING ANALYSIS (CONT)

- SURVIVABILITY/VULNERABILITY -- ARMORED VEHICLES
  - •• BALLISTIC PROTECTION -- COMPARABLE
  - •• PROBABILITY OF SUFFERING A MOBILITY KILL -- COMPARABLE
  - •• THERMAL AND RADAR SIGNATURES -- COMPARABLE
  - •• VISUAL SIGNATURE -- TRACKS ARE MARGINALLY SUPERIOR
  - •• ACOUSTIC SIGNATURES -- WHEELS SIGNIFICANTLY QUIETER



HEADQUARTERS
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SLIDE 34 - ENGINEERING ANALYSIS (CONT) - GUN PLATFORM

As a gun platform firing from a stationary position, wheeled and tracked vehicles are comparable for gun calibers below 75mm. For larger caliber guns, the first round probability of hit, P(h), is comparable between the two automotive configurations. The second round P(h) is degraded for wheeled vehicles if it is fired before the chassis damps out from the recoil of the previous round. This is a particular problem with autoloaders that offer very fast cycle time. This problem is caused by undamped tire-flexing under the recoil of the gun and is intrinsic with the wheeled vehicle design. The problem can be reduced by going to a soft-recoil or low velocity gun.

When the vehicle is moving, the tracked vehicle offers a superior platform since the gun stabilization system only has to counteract suspension movements. In a wheeled vehicle, the stabilization system has to overcome tire-flex also. The problem gets worse as you reduce the number of axles from an 8X8 to a 6X6 or 4X4 configuration.

Backup Slide - 29

ENGINEERING ANALYSIS (CONT)

- GUN PLATFORM
  - •• VEHICLE STATIONARY
    - BELOW 75 MM - WHEELED AND TRACKED VEHICLES ARE COMPARABLE
    - ABOVE 75 MM
      - -- FIRST ROUND P(H) APPROXIMATELY EQUAL
      - -- SECOND ROUND P(H) LOWER FOR WHEELED VEHICLE IF FIRED WITHIN 4 SECONDS (105 MM) DUE TO TIRE FLEXING
      - -- PROBLEM CAN BE REDUCED BY GOING TO SOFT-RECOIL GUN
  - •• VEHICLE MOVING
    - -- TRACKED VEHICLES ARE SUPERIOR DUE TO ABSENCE OF TIRE FLEXING

SLIDE 35 - ENGINEERING ANALYSIS (CONT) - MISSILE PLATFORM

As a missile platform, wheeled and tracked vehicles are comparable when firing from rest. When firing on the move, the guidance technology employed in the missile is the determinant of which vehicle is the superior platform.

For optically guided missiles, such as the TOW, it is not practical to fire this type of missile from a moving land vehicle. The problem is that even with a stabilization system the gunner is incapable of maintaining the target designator on the target while the missile is in flight with sufficient accuracy to produce an acceptable probability of hit. Additionally, line of sight must be maintained with the target while the missile is in flight and doing so exposes the firing vehicle to enemy counterfire for an extended period of time.

For externally designated missiles, such as the Hellfire, wheeled and tracked vehicles are comparable. With this type of a missile, the only requirement of the launch platform is to fire the missile in the general direction of the target. The external target designator guides the missile.

For a missile that requires target lock on prior to launch, a tracked vehicle offers a superior cross-country platform. The situation is comparable to the problem one encounters with a gun stabilization system and the tire flex problem that occurs with wheeled vehicles.

ENGINEERING ANALYSIS (CONT)

- MISSILE PLATFORM
  - •• VEHICLE STATIONARY
    - WHEELED AND TRACKED VEHICLES ARE COMPARABLE
  - •• VEHICLE MOVING
    - OPTICALLY GUIDED MISSILE (TOW)
      - -- NOT PRACTICAL TO FIRE THIS TYPE OF MISSILE FROM MOVING LAND VEHICLE
    - EXTERNALLY DESIGNATED MISSILE (HELLFIRE)
      - -- WHEELED AND TRACKED VEHICLES ARE COMPARABLE
    - LOCKON BEFORE LAUNCH MISSILE
      - -- TRACKED VEHICLES ARE SUPERIOR DUE TO ABSENCE OF TIRE FLEXING

HEADQUARTERS
TRADOC

SLIDE 36 - ENGINEERING ANALYSIS (CONT) - FUEL CONSUMPTION

Wheeled vehicles enjoy a considerable advantage in fuel consumption. This advantage is on the order of 50% for comparable vehicles in the 10 to 20 ton GVW class. This difference is caused by the reduced rolling resistance of the wheeled configuration.

ENGINEERING ANALYSIS (CONT)

- FUEL CONSUMPTION
  - •• IN THE 10 TO 20 TON GVW CLASS, TRACKED VEHICLES WILL BURN APPROXIMATELY TWICE AS MUCH FUEL AS WHEELED VEHICLES

HEADQUARTERS
TRADOC

SLIDE 37 - ENGINEERING ANALYSIS (CONT) - RELIABILITY AND MAINTAINABILITY

Only two Reliability and Maintainability (R&M) tests have been conducted where comparable wheeled and tracked vehicles were evaluated head-to-head performing identical mission profiles. The results of both tests were inconclusive from a wheels versus tracks perspective. The Armored Reconnaissance Scout Vehicle (ARSV) test favored the tracked vehicle and the Light Armored Vehicle (LAV) test favored the wheeled vehicle. In both tests, it was more a case of the winning vehicle working while the alternative vehicles suffered a lot of down time for a multitude of reasons independent of the automotive configuration.

Backup Slide - 30

ENGINEERING ANALYSIS (CONT)

- RELIABILITY AND MAINTAINABILITY
  - •• ONLY TWO RAM TESTS HAVE BEEN CONDUCTED FOR COMPARABLE WHEELED AND TRACKED VEHICLES PERFORMING SIMILAR VEHICLE MISSION ROLES
    - ARMORED RECONNAISSANCE SCOUT VEHICLE (ARSV) --1974
      - -- PROTOTYPE VEHICLES
      - -- TRACKED VEHICLE SUPERIOR
    - LIGHT ARMORED VEHICLE (LAV) -- 1982
      - -- NDI VEHICLES
      - -- WHEELED VEHICLE SUPERIOR

HEADQUARTERS
TRADOC

SLIDE 38 - ENGINEERING ANALYSIS (CONT) - RELIABILITY AND MAINTAINABILITY (CONT)

The only historical wheels versus tracks data located for tactical high mobility vehicles are the M113 family of tracked vehicles versus the M561 Gamma-Goat, the M520 GOER, the HMMWV and the LAV. If we look only at mission failures related to the automotive components of these vehicles, we see that on average the wheeled vehicles enjoy about a 40% advantage in mean miles between operational mission failure (MMBOMF). An operational mission failure is an equipment failure that would render the vehicle incapable of completing its assigned mission. Minor failures that can be deferred for some period of time are not counted. It is interesting to note that if we look only at the two newer designs, this advantage increases to around 100% in favor of the wheels.

One note of caution, the depicted data were statistically adjusted to arrive at a common basis of chassis failure definition. As such, these figures should be used with caution, and looked upon as an order of magnitude estimate only. Additionally, wheeled vehicles are normally not operated in the same manner as tracks. Some of this observed difference may be attributable to the more benign environment where wheeled vehicles normally operate.

ENGINEERING ANALYSIS (CONT)

- **RELIABILITY AND MAINTAINABILITY (CONT)**

TACTICAL HIGH MOBILITY VEHICLES

	AUTO MMBOMF
WHEELED	
M561 (GAMMA-GOAT)	522
M520 (GOER)	758
LAV	1321
M998 (HMMWV)	1461
AVERAGE	1016
TRACKED	
M113 (FAMILY)	726

HEADQUARTERS
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SLIDE 39 - BOTTOM LINE - ENGINEERING ANALYSIS

The bottom line of the engineering analysis is that tracked vehicles are more compact, and offer a superior gun platform while wheeled vehicles are quieter, have lower fuel consumption, are self-deployable within a theater, and have superior reliability and maintainability characteristics.

BOTTOM LINE -- ENGINEERING ANALYSIS

- TRACKED VEHICLES
  - MORE COMPACT
  - SUPERIOR GUN PLATFORM
- WHEELED VEHICLES
  - QUIETER
  - LOWER FUEL CONSUMPTION
  - SUPERIOR RELIABILITY AND MAINTAINABILITY CHARACTERISTICS

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SLIDE 40 - COST ANALYSIS

The final portion of our analysis is cost. Here we looked at the three major categories that contribute to overall life-cycle cost.

COST ANALYSIS

HEADQUARTERS
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SLIDE 41 - CCST ANALYSIS (CONT) - RDT&E AND PROCUREMENT

The first area we examined was Research, Development, Test and Evaluation Cost (RDT&E). Unfortunately, due to the absence of data, we could not confirm any clear trends. Most recently procured light vehicles have been non-developmental items that were already in production or the RDT&E costs could not be broken out from available information.

We were more successful with procurement cost. The data cleanly break into two categories, thin-skinned and armored. We find that with thin-skinned vehicles, such as HMMWV, the M548, and the BV206 Small Unit Support Vehicle (SUSV), wheeled vehicles are 50 to 66 percent lower in procurement cost on a per pound of payload basis. This difference is primarily attributable to the ability to use commercially available components in the wheeled vehicles. A note of caution: these cost differences have been observed in vehicles that offer differing levels of off-road mobility. We were not able to make any comparisons for thin-skinned wheeled and tracked that offered directly comparable levels of operational mobility.

With armored vehicles, such as the LAV and M113, we were not able to detect any clear trends in procurement cost. The limited production runs of armored vehicles make them more sensitive to buy quantities or manufacturer facilities than any wheels versus tracks considerations. Additionally, we found that the mission equipment on an armored vehicle represents a significant percentage of the procurement cost. This is a primary contributor to the perception that tracked vehicles are much more expensive than wheeled vehicles since tracked vehicles normally carry extensive mission equipment.

It is likely that armored wheeled and tracked combat vehicles would be comparable in procurement cost if they were comparably equipped and designed to perform the same mission. The Cadillac-Gage Company gave us nearly equal estimates of procurement cost for their wheeled V-300A1 Commando and their tracked Commando Stingray when both vehicles were equipped with the same 105mm weapon system.

Backup Slides - 31, 32 & 33

COST ANALYSIS

- RESEARCH, DEVELOPMENT, TEST AND EVALUATION (RDT&E) COSTS
  - •• NO DATA
  - •• MOST LIGHT VEHICLES ARE NDI
- PROCUREMENT COSTS
  - •• THIN-SKINNED VEHICLES (TRUCKS, LOGISTICS VEHICLES, ETC.)
    - WHEELED VEHICLES ARE 50 TO 66 PERCENT LOWER IN COST
  - •• ARMORED VEHICLES (LAV, M113, ETC.)
    - NO CLEAR TRENDS
    - DIFFERENCE PROBABLY LESS THAN 10%
    - MISSION EQUIPMENT REPRESENTS UP TO 80% OF ARMORED VEHICLE PROCUREMENT COST

HEADQUARTERS
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SLIDE 42 - COST ANALYSIS (CONT) - LAV VS M113

To illustrate the contribution of mission equipment to the overall procurement cost of an armored vehicle, we have depicted here the procurement cost of the various versions of the General Motors 8X8 Light Armored Vehicle (LAV) and the various versions of the FMC M113. The costs of the two vehicle configurations are not directly comparable because different assumptions about buy quantity were used, but within a given vehicle family we can compare.

If we look specifically at the LAV family, we see that the base LAV costs around $286K. As we add mission equipment to develop the various versions of the combat vehicle family, we see the percentage of the total procurement cost represented by the base vehicle progressively reduced as we approach the top-of-the-line TOW II version. Here we see that of the $828K procurement cost for this combat system, only 35%, or $286K, is represented by the base vehicle. The remaining $542K, or 65% of the procurement price is generated by the mission equipment required to transform the base vehicle into the TOW II version. We see this same escalation in procurement cost for the tracked M113 family.

COST ANALYSIS (CONT)

MISSION EQUIPMENT COSTS	UNIT COST (FY-86)	PERCENT BASE VEHICLE REPRESENTS OF UNIT COST
GM 8 X 8 (LAV)		
BASE VEHICLE	$286,000	100
RECOVERY	400,000	72
COMMAND & CONTROL	424,000	67
APC	448,000	64
25 MM GUN	658,000	43
TOW II	828,000	35
FMC M113		
BASE VEHICLE	$153,000	100
CHEMICAL (SMOKE)	173,000	88
COMMAND & CONTROL	188,000	81
TOW II	437,000	35
FISTV (LESS G/VLLD)	502,000	30
20 MM AD GUN	979,000	16

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SLIDE 43 - COST ANALYSIS (CONT) - OPERATING AND SUPPORT COSTS

The available information on a direct wheels versus tracks Operating and Support (O&S) cost comparison is rather sketchy because historically we have not looked at the two vehicle configurations as competitors. The 1980 Mobile Protected Gun System (MPGS) Cost and Operational Effectiveness Analysis (COEA) is the only direct comparison of tactical high mobility wheeled and tracked vehicles we were able to identify. In this study, it was projected that the wheeled alternative would be 32 percent lower in O&S cost than the average of the tracked alternatives.

Foreign experience may be a little more illuminating since they have used wheeled and tracked vehicles in directly comparable roles. In a 1982 study on their future APC, the Dutch projected a 25% annual savings in using a wheeled APC over a tracked. It is interesting to note that despite this cost savings, the Dutch decided to retire their fleet of wheeled APCs and replace them with a totally tracked fleet. To date, the Canadian operational experience with their GM Grizzly 6x6 APC has shown that the wheeled vehicle is about 28 percent lower in operating cost. Similarly, the French report about a 33 percent life-cycle cost savings with their wheeled armored vehicle fleet.

It would take a detailed controlled study to get a high resolution answer to the O&S question. Even so, based on the consistency of our survey, it appears that one would experience a chassis related 25 to 33 percent reduction in O&S cost by using wheeled armored vehicles. Weapon systems cost would probably be comparable between the two vehicle configurations.

One note of caution, it is very difficult to operate wheeled and tracked combat vehicles in exactly the same manner and normally wheeled vehicles are not taken off-road as much as tracks. It is probable that some of the observed O&S cost savings associated with wheeled armored vehicles is attributable to the more benign environment in which they normally operate.

Backup Slide - 34

COST ANALYSIS (CONT)

- OPERATING AND SUPPORT (O&S) COSTS
  - •• 1980 MPGS COEA
    - WHEELED ALTERNATIVE -- 32 PERCENT LOWER IN O&S COSTS
  - •• 1982 NETHERLANDS APC STUDY (DAF 408 & FMC M113)
    - WHEELED DAF 408 -- 25 PERCENT LOWER IN O&S COSTS
  - •• 1984 CANADIAN APC OPERATIONAL EXPERIENCE (GM GRIZZLY & FMC M113)
    - WHEELED GM GRIZZLY -- 28 PERCENT LOWER IN O&S COSTS
  - •• 1984 FRENCH OPERATIONAL EXPERIENCE
    - WHEELED ARMORED VEHICLES ARE 33 PERCENT LOWER IN LIFE CYCLE COSTS

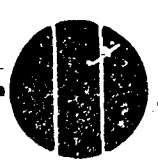
HEADQUARTERS
TRADOC

SLIDE 44 - BOTTOM LINE - COST ANALYSIS

In general, these are the bottom line conclusions of our cost analysis.

BOTTOM LINE -- COST ANALYSIS

- RDT & E
  - •• NO DATA
- PROCUREMENT
  - •• THIN-SKINNED WHEELED
    - — WHEELED VEHICLES ARE 50 TO 66 PERCENT LOWER IN COST
  - •• LIGHT ARMORED VEHICLES
    - — COSTS ARE COMPARABLE
- O&S
  - •• THIN-SKINNED VEHICLES
    - — NO COMPARABLE DATA
  - •• LIGHT ARMORED VEHICLES
    - — WHEELED ARMORED VEHICLES ARE 25 TO 33 PERCENT LOWER IN COST



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SLIDE 45 - STUDY CONCLUSIONS

In summary, the general conclusions we arrived at in the course of this study effort are . . . .

STUDY CONCLUSIONS

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SLIDE 46 - STUDY CONCLUSIONS

Wheeled vehicles are clearly the automotive configuration of choice for vehicle mission roles requiring either Tactical Support or Tactical Standard levels of operational mobility. These vehicle mission roles are performed primarily on improved surfaces and wheeled vehicles are clearly the vehicle of choice for operations in this environment.

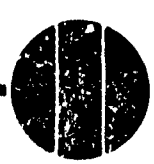
The only place tracked vehicles are currently used and the only place they should be used is in vehicle mission roles requiring Tactical High levels of operational mobility. Within this category, for gross vehicle weights up to around 10 tons, wheeled vehicles are preferred. It does not present a very difficult design problem to build highly mobile wheeled vehicles in this weight class and the O&S cost savings potential of a wheeled platform dictates that vehicles in this weight class should be wheeled.

Above 20 tons gross vehicle weight, tracked vehicles are required. The size and mechanical complexity of competitive high-mobility wheeled vehicles tends to make them impractical for military use.

In the 10 to 20 ton class, a gray area exists between wheeled and tracked vehicles and it is contingent upon the operational requirements of the specific vehicle mission role as to which vehicle configuration is the preferred alternative.

STUDY CONCLUSIONS

- WHEELED VEHICLES PREFERRED FOR "TACTICAL SUPPORT" OR "TACTICAL STANDARD" LEVELS OF OPERATIONAL MOBILITY
- FOR A "TACTICAL HIGH" LEVEL OF OPERATIONAL MOBILITY
  - •• UP TO 10 TONS GVW - WHEELED VEHICLES PREFERRED
  - •• OVER 20 TONS GVW - TRACKED VEHICLES REQUIRED
  - •• 10 TO 20 TONS GVW - "GRAY AREA"



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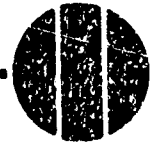
In the 10 to 20 ton gross vehicle weight class, if one were to choose a wheeled vehicle, the general advantages and disadvantages associated with its use are delineated here. It is interesting to note that most of the advantages associated with the use of wheeled armored vehicles are in the cost and support arena while their disadvantages come at the expense of operational utility.

Backup Slides - 35, 36, 37, 38, 39 & 40

STUDY CONCLUSIONS (CONT)

- IN THE 10 TO 20 TONS GVW CLASS, THE MAJOR ADVANTAGES AND DISADVANTAGES OF USING A WHEELED VEHICLE
  - •• ADVANTAGES
    - LOWER LIFE-CYCLE COSTS
    - LOWER FUEL CONSUMPTION
    - LOWER ACOUSTIC SIGNATURE
    - INTRA-THEATER SELF-DEPLOYMENT CAPABILITY
    - BETTER RELIABILITY AND MAINTAINABILITY CHARACTERISTICS
  - •• DISADVANTAGES
    - REDUCED OFF-ROAD MOBILITY
    - REDUCED MANEUVERABILITY
    - REDUCED WEIGHT GROWTH POTENTIAL
    - INFERIOR LARGE CALIBER GUN PLATFORM
    - LARGER OVERALL SIZE



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SLIDE 48 - STUDY CONCLUSIONS (CONT)

Because of these operational shortfalls, we do not see the 10 to 20 ton wheeled armored vehicle as a viable combat platform. Given the direction our doctrine is moving us, unrestricted off-road mobility is of paramount importance in our ability to wage war. If we possess superior mobility, we can operate at a faster pace and in terrain that may be inaccessible to our enemy. These can be the critical factors in our ability to successfully engage and defeat a numerically superior opponent.

For Combat Support and Combat Service Support vehicle mission roles, unrestricted mobility is not the primary driver as it is with combat vehicles. Freedom of movement is important but in general, support vehicles have greater flexibility in selecting their direction and speed of movement and can bypass marginal terrain. Wheeled vehicles should be considered as competitors to tracked vehicles for these support mission roles. The decision as to whether a wheeled or tracked vehicle is the preferred solution to a specific vehicle requirement is best left to the cost effectiveness analysis process.

STUDY CONCLUSIONS (CONT)

- TACTICAL HIGH MOBILITY (10 TO 20 TON GVW CLASS)
  - •• COMBAT -- TRACKED VEHICLES PREFERRED
  - •• COMBAT SUPPORT -- WHEELED AND TRACKED VEHICLES COMPETITIVE
  - •• COMBAT SERVICE SUPPORT -- WHEELED AND TRACKED VEHICLES COMPETITIVE

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SLIDE 49 - STUDY CONCLUSIONS (CONT) - MATRIX

In matrix form, the results of our study would appear like this.

WHEELED VERSUS TRACKED VEHICLES

MOBILITY REQUIREMENT	MISSION AREA		
	CBT	CS	CSS
TACTICAL SUPPORT			
ALL WEIGHT CLASSES	WHEELED	WHEELED	WHEELED
TACTICAL STANDARD			
ALL WEIGHT CLASSES	WHEELED	WHEELED	WHEELED
TACTICAL HIGH			
UP TO 10 TONS GVW	WHEELED	WHEELED	WHEELED
10 TO 20 TONS GVW	TRACKED	WH & TK	WH & TK
OVER 20 TONS GVW	TRACKED	TRACKED	TRACKED

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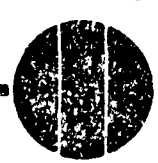
SLIDE 50 - STUDY CONCLUSIONS (CONT) - PERCEPTIONS

In the beginning, we noted several commonly held perceptions regarding the military use of wheeled armored vehicles. We will now revisit those perceptions in light of the results of our study.

PERCEPTIONS OF WHEELED ARMORED VEHICLES



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SLIDE 51 - PERCEPTIONS OF WHEELED ARMORED VEHICLES

Acceptable performance? The advocates of wheeled armored vehicles argue that the vehicles offer adequate performance to be considered viable military platforms. Wheeled vehicles are very competitive with tracks below the 10 ton GVW level. As you transition into gross vehicle weights above 10 tons, wheeled vehicles start increasing in size and mechanical complexity while trading off soft-soil mobility. Around the 20 ton level, high-mobility wheeled vehicles become impractical for general military use. The area of competition between wheeled and tracked armored vehicles occurs in the 10 to 20 ton band. Within this band, wheeled vehicles suffer some intrinsic operational shortfalls that compromise their effectiveness as combat vehicles. Additionally, wheeled armored vehicles are intrinsically larger than their tracked counterparts which aggravates the air transport problem.

Lower cost? The advocates of wheeled armored vehicles like to argue that wheeled vehicles are across the board lower in life-cycle cost. We were not able to substantiate this claim and it appears to be very misleading. It is possible to build relatively austere wheeled armored vehicles at a comparatively low cost. These vehicles are little more than armored commercial trucks and they have relatively limited off-road capabilities. High-mobility wheeled armored vehicles are special purpose vehicles that are ground-up new designs, very much like tracked vehicles. The base version of the Marine Corps' LAV costs around $285K; this compares with $153K for the base M113. The contention that one can procure high performance wheeled armored at lower cost is simply not borne out by the available information. It is in operating and support costs that wheeled armored vehicles have a very definite cost advantage. The upper bound on this cost savings in on the order of 25 to 33 percent and is chiefly the result of lower fuel consumption and longer tire life.

PERCEPTIONS OF WHEELED ARMORED VEHICLES

- ACCEPTABLE PERFORMANCE?
  - MARGINAL ABOVE 10 TONS GVW
  - NOT PRACTICAL ABOVE 20 TONS GVW
  - INFERIOR
    - —OFF-ROAD MOBILITY
    - —GUN PLATFORM
    - —MANEUVERABILITY
  - LARGER OVERALL SIZE
- LOWER COST?
  - RDT&E -- NO DATA
  - PROCUREMENT -- COMPARABLE
  - O&S -- 25 TO 33 PERCENT LOWER

HEADQUARTERS
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SLIDE 52 - PERCEPTIONS OF WHEELED ARMORED VEHICLES (CONT)

Expanded foreign use? The advocates of wheeled armored vehicles often argue that the whole world is making a massive shift to wheeled armor. This is simply not true.

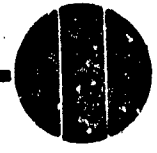
France is the only major non-communist military power that has made a heavy commitment to wheeled armored vehicles. France has some unique treaty obligations that have arisen out of their former colonial possessions and wheeled armored vehicles are ideally suited to support these obligations. France retains the tracked vehicle as an integral component of the tank-helicopter attack team in its heavy forces. Other non-communist countries that use wheeled armor tend to restrict its use to various support roles that were previously supported by trucks.

The Soviet Union and its allies made a heavy commitment to wheeled armor following World War II. This commitment continued up to the introduction of the BMP in the late 1960s. Since that time, the Soviet Union has been upgrading its motorized forces by replacing the wheeled armored vehicles with tracked vehicles.

The third world is the only area where a large scale embracement of wheeled armor is taking place and it is primarily in response to their limited requirements and fiscal constraints.

PERCEPTIONS OF WHEELED ARMORED VEHICLES (CONT)

- EXPANDED FOREIGN USE?
  - WESTERN COUNTRIES
    - —FRANCE IS MOST EXTENSIVE USER OF WHEELED ARMOR
    - —OTHER COUNTRIES TEND TO USE WHEELED ARMOR AS A REPLACEMENT FOR THIN-SKINNED VEHICLES IN VARIOUS SUPPORT ROLES
  - WARSAW PACT
    - —HEAVY COMMITMENT TO WHEELED ARMOR FOLLOWING WWII
    - —HAVE BEEN EXPANDING USE OF TRACKED ARMOR SINCE THE LATE 1960's
  - THIRD WORLD
    - —EXTENSIVE USERS OF WHEELED ARMOR
      - --LIMITED THREAT
      - --INTERNAL SECURITY
      - --ECONOMIC CONSIDERATIONS



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SLIDE 53 - PERCEPTIONS OF WHEELED ARMORED VEHICLES (CONT)

Another factor contributing to the impression of greatly expanded use of wheeled armored vehicles is the number of manufacturers competing in the marketplace. A manufacturer can get into the wheeled armor vehicle business with less capital investment than would be required for entry into the tracked vehicle market. Consequently, there are almost twice as many manufacturers in the wheeled armor business. This leads to expanded press coverage as the various trade journals review the different manufacturers offerings. Additionally, because of greater competition, manufacturers of wheeled armor engage in extensive advertising in the trade journals which creates the impression of a greatly expanded market.

Backup Slides - 41 & 42

PERCEPTIONS OF WHEELED ARMORED VEHICLES (CONT)

- EXPANDED FOREIGN USE? (CONT)
  - MORE MANUFACTURERS COMPETING IN MARKETPLACE
    - —WHEELED ARMOR
      - --40 MANUFACTURERS
      - --24 COUNTRIES
    - —TRACKED ARMOR
      - --23 MANUFACTURERS
      - --16 COUNTRIES
  - EXTENSIVE PRESS COVERAGE
  - EXTENSIVE ADVERTISING

HEADQUARTERS
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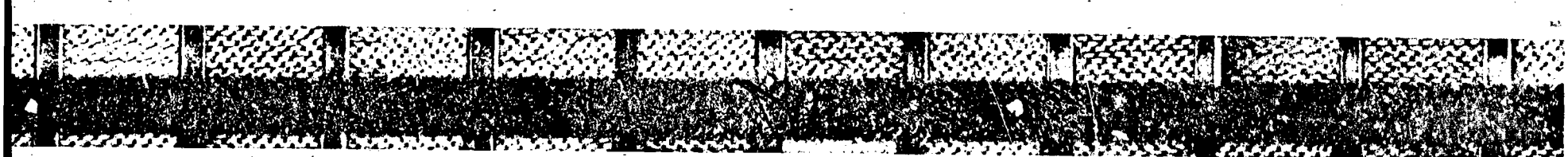
SLIDE 54 - FUTURE VEHICLE REQUIREMENTS

How does all of this impact our future vehicle requirements?



FUTURE VEHICLE REQUIREMENTS

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SLIDE 55 - PROJECTED VEHICLE REQUIREMENTS

In our survey of the TRADOC Schools and Centers, we identified this group of projected vehicle requirements for which either wheeled or tracked vehicles could conceivably support the vehicle mission role. One should be cautioned that these are only projected requirements that have arisen out of the Mission Area Analysis (MAA) Process. Some of these have moved on into the actual requirements definition process but most have not. The common denominators of this list of projected vehicle requirements are armor, forward area operations and most are Combat Support or Combat Service Support.

FUTURE VEHICLE REQUIREMENTS

- **PROJECTED VEHICLE REQUIREMENTS**
  - •• ARMORED GUN SYSTEM (AGS) (ARMOR)
  - •• ARMORED FORWARD AREA REARM VEHICLE (AFARV) (ARMOR)
  - •• ARMORED REFUEL VEHICLE (QUARTERMASTER)
  - •• ELEVATED TARGET ACQUISITION SYSTEM (ETAS) VEHICLE (FIELD ARTILLERY)
  - •• ARMORED FORWARD AREA IEW VEHICLE (INTELLIGENCE)
  - •• ARMORED FORWARD AREA SMOKE GENERATOR (CHEMICAL)
  - •• ARMORED FORWARD AREA CONTACT TEAM VEHICLE (MISSILE AND MUNITIONS)
  - •• ARMORED NBC RECONNAISSANCE VEHICLE (CHEMICAL)
  - •• ARMORED MAINTENANCE VEHICLE (ORDNANCE)
  - •• ARMORED ENGINEER VEHICLE (ENGINEER)

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SLIDE 56 - DRIVING FACTORS

There are three main factors driving these vehicular requirements: threat, evolving doctrine and fielding of the M1 and M2/3. The increasing capabilities of threat forces and the proliferation of chemical/nuclear weapons are generating higher levels of ballistic and NBC protection requirements in all functional areas of the battlefield. Implementation of AirLand Battle Doctrine has brought a stronger offensive maneuver orientation to the battlefield and placed greater importance on unrestricted mobility. The AirLand Battle 2000 - Army 21 concept is going even further and looking at a nonlinear battlefield where our traditional concepts of DS and GS support will have to be modified. Fielding of the Abrams Main Battle Tank and the Bradley Infantry Fighting Vehicle have given the combat elements much greater speed, mobility and a greater requirement for class III and V consumables. The combination of these factors is giving rise to the increased demand for greater mobility, protection and capacity in the support forces.

• DRIVING FACTORS

•• THREAT
- BALLISTIC/NBC PROTECTION REQUIREMENTS

•• AIRLAND BATTLE DOCTRINE
- OFFENSIVE ORIENTATION
- GREATER TACTICAL MOBILITY
- CSS CARRIED OUT FURTHER FORWARD

•• AIRLAND BATTLE 2000 -- ARMY 21 CONCEPT
- NONLINEAR BATTLEFIELD
- ACCOMPANYING CSS

•• FIELDING THE ABRAMS MBT AND BRADLEY IFV/CFV
- INCREASED SPEED AND MOBILITY OF COMBAT ELEMENTS
- OUT PERFORM CURRENT CS ELEMENTS
- INCREASED CLASS III AND V SUPPORT REQUIREMENTS

HEADQUARTERS
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SLIDE 57 - FUTURE VEHICLE REQUIREMENTS

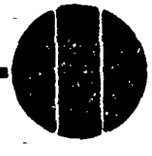
The decision as to whether a wheeled or tracked vehicle is the most cost effective solution to these vehicle requirements is dependent upon the specific vehicle mission role and the probable scenarios where the vehicle mission role will be performed. Wheeled and tracked vehicles both have their place on the modern battlefield and should be looked at as complementary systems rather than competitors.

TRADOC will ensure that wheeled and tracked alternatives are examined in all future cost effectiveness analyses where it is conceivable that a wheeled or tracked chassis could support the vehicle requirement.

This concludes the formal portion of this Wheeled Versus Tracked Vehicle Study briefing.

FUTURE VEHICLE REQUIREMENTS (CONT)

- WHEELED AND TRACKED ALTERNATIVES WILL BE EXAMINED IN ALL FUTURE TRADOC COST AND OPERATIONAL EFFECTIVENESS ANALYSES WHERE THE VEHICLE MISSION ROLE COULD CONCEIVABLY BE SUPPORTED BY EITHER AUTOMOTIVE CONFIGURATION



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Chapter 2

Specific Questions

SLIDE 1 - SPECIFIC QUESTIONS

The original tasking message asked several specific questions that for the sake of brevity, were not answered in the main briefing. This section provides answers to the questions omitted from the main briefing.

SPECIFIC QUESTIONS

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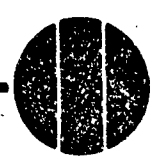
SLIDE 2 - TRAILER TOWING

SELF-EXPLANATORY

IS THERE A DIFFERENCE BETWEEN WHEELED AND TRACKED VEHICLES IN THE DEGRADATION TO OVERALL VEHICLE MOBILITY CAUSED BY TOWING A TRAILER?



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SLIDE 3 - TRAILER TOWING

In off-road towing situations, mobility under tow is a reflection of the underlying off-road mobility of the prime mover. The Vehicle Cone Index (VCI) is a good general measure of soft-soil mobility and the amount of VCI degradation the vehicle/trailer combination suffers is primarily a function of the ratio of the weight of the prime mover to the towed trailer. The VCI degradation suffered by wheeled and tracked vehicles tends to be constant (e.g., both vehicle configurations would experience a comparable 10 point increase in VCI) but since a tracked vehicle normally carries a VCI rating 10 to 15 points lower than a comparable wheeled vehicle, the net reduction in terrain mobility will normally be less for a track vehicle. Consequently, the tracked vehicle is the preferred prime mover for cross-country trailer towing.

With high-mobility vehicles, the limiting factor on cross-country speed normally is the trailer rather than the prime mover. The simple suspension systems found in most trailers are not designed to accept the higher levels of shock and vibration imposed by the higher off-road speeds attained by modern high-mobility vehicles.

TRAILER TOWING

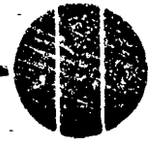
- IN TRAILER TOWING SITUTATIONS, OFF-ROAD MOBILITY IS A REFLECTION OF THE BASIC OFF-ROAD MOBILITY OF THE TOWING VEHICLE
- WHEELED AND TRACKED VEHICLES ARE UNIFORMLY DEGRADED IN THEIR PERFORMANCE WHEN TOWING A TRAILER
- TRACKED VEHICLES HAVE SUPERIOR SOFT/WET SOIL MOBILITY AND ARE BETTER SUITED FOR TRAILER TOWING IN MARGINAL TERRAIN CONDITIONS
- WHEELED VEHICLES ARE PREFERRED FOR ON-ROAD TRAILER TOWING
- THE TRAILER MAY BE THE LIMITING FACTOR IN THE MAXIMUM SPEED OBTAINABLE BY THE PRIME MOVER/TRAILER COMBINATION

HEADQUARTERS
TRADOC

SLIDE 4 - ONBOARD ELECTRIC POWER GENERATION

SELF-EXPLANATORY

IS THERE A DIFFERENCE BETWEEN WHEELED AND TRACKED VEHICLES IN THEIR CAPABILITY FOR ONBOARD ELECTRIC POWER GENERATION?



HEADQUARTERS
TRADOC

SLIDE 5 - ONBOARD ELECTRIC POWER GENERATION

The capability for onboard electric power generation is a function of the residual power available from the main power plant for turning a generator/alternator or having space in the vehicle for mounting an auxiliary power unit (APU). For generating electric power from the main power plant, wheeled and tracked vehicles with similar power to weight ratios are comparable. For generating electric power with an APU, primarily it is a matter of finding space within or on the vehicle to mount the unit. Because of drive train packaging efficiencies, it is easier to find space in a tracked vehicle to mount an APU if the overall size of the vehicle is constrained (e.g., designing a vehicle for air transport). Additionally, the tracked vehicle is less likely to suffer any mobility degradation from carrying the additional weight of the APU.

ONBOARD ELECTRIC POWER GENERATION

- THE ABILITY TO GENERATE ONBOARD ELECTRIC POWER IS A FUNCTION OF THE RESIDUAL POWER AVAILABLE FROM THE MAIN POWER PLANT OR THE AVAILABLE SPACE FOR MOUNTING AN AUXILIARY POWER UNIT
- AS SUCH, IT IS A FUNCTION OF THE BASIC POWER TO WEIGHT RATIO OF THE VEHICLE AND THE PACKAGING EFFICIENCY OF THE DRIVE TRAIN
- COMPARABLE WHEELED AND TRACKED VEHICLES, WITH SIMILAR POWER TO WEIGHT RATIOS, WOULD BE COMPARABLE IN THEIR ABILITY TO GENERATE ONBOARD ELECTRIC POWER FROM THE MAIN POWER PLANT
- IT WOULD BE EASIER TO DESIGN AN ONBOARD POWER GENERATION CAPABILITY INTO A TRACKED VEHICLE IF THE OVERALL VEHICLE SIZE WAS CONSTRAINED

HEADQUARTERS
TRADOC

SLIDE 6 - EXCLUSIVE VEHICLE MISSION ROLES

SELF-EXPLANATORY

ARE THERE ANY VEHICLE MISSION ROLES THAT OUGHT TO BE EXCLUSIVELY ACCOMPLISHED BY WHEELED OR TRACKED VEHICLES?

HEADQUARTERS
TRADOC

SLIDE 7 - EXCLUSIVE VEHICLE MISSION ROLES

Wheeled vehicles are preferred for all vehicle mission roles requiring either Tactical Support or Tactical Standard levels of operational mobility. Both of these operational mobility levels primarily involve on-road travel and wheeled vehicles are superior to tracked vehicles for on-road operations.

For vehicle mission roles requiring Tactical High levels of operational mobility, the decision of wheels versus tracks varies with the gross vehicle weight and the intended role of the vehicle.

For gross vehicle weights (GVW) up to 10 tons, wheeled vehicles are preferred. In this weight class, well designed high-mobility wheeled vehicles offer competitive off-road performance at lower operating and support costs.

Above 10 tons GVW, tracked vehicles are preferred for all combat roles. The tracked vehicle offers several intrinsic mobility/operational advantages (e.g., gap crossing, maneuverability, soft/wet soil mobility, gun platform stability, etc.) that are of paramount importance for the combat vehicle. For the combat support and combat service support mission roles, wheeled vehicles compete with tracked vehicles up to 20 tons GVW. The choice of either a wheeled or tracked solution for these vehicle requirements is best left to the decision process and the supporting cost effectiveness analysis where specific vehicle alternatives are evaluated in the context of specific mission requirements.

Above 20 tons GVW, wheeled vehicles of reasonable proportions or mechanical complexity are not competitive with tracked vehicles in off-road mobility. Consequently, 20 tons GVW should be considered a practical upper limit for Tactical High Mobility wheeled vehicles.

EXCLUSIVE VEHICLE MISSION ROLES

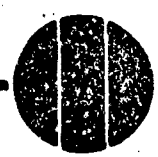
- WHEELED VEHICLES
  - ALL VEHICLES REQUIRING EITHER "TACTICAL SUPPORT" OR "TACTICAL STANDARD" LEVELS OF OPERATIONAL MOBILITY
  - ALL VEHICLES REQUIRING A "TACTICAL HIGH" LEVEL OF OPERATIONAL MOBILITY BUT HAVING A GROSS VEHICLE WEIGHT LESS THAN 10 TONS
- TRACKED VEHICLES
  - ALL VEHICLES HAVING AN GROSS VEHICLE WEIGHT IN EXCESS OF 20 TONS AND REQUIRING A "TACTICAL HIGH" LEVEL OF OPERATIONAL MOBILITY
  - COMBAT VEHICLES HAVING A GROSS VEHICLE WEIGHT IN EXCESS OF 10 TONS

HEADQUARTERS TRADOC

SLIDE 8 - SUBSTITUTE WHEELS FOR TRACKS DURING PEACETIME

SELF-EXPLANATORY

IN PEACETIME COULD WHEELED VEHICLES BE SUBSTITUTED FOR TRACKED VEHICLES TO SAVE MAINTENANCE AND OTHER COSTS?



HEADQUARTERS
TRADOC

SLIDE 9 - SUBSTITUTE WHEELS FOR TRACKS DURING PEACETIME

We surveyed the TRADOC Schools and Centers with this question and there was general unanimity that this would not be a desirable course of action to pursue. The primary area where peacetime substitutions could be effected is in maneuver training and this is already being done to a limited degree with the wheeled vehicles organic to the units.

A major concern expressed by the Schools and Centers is the lack of combat readiness that would inevitably result from training on different equipment than that which would be used during wartime. Current scenarios are very much of the "come as you are" variety and a learning curve for transitioning from peacetime to wartime equipment would be unacceptable in the short amount of time available during an actual deployment. Additionally, considerable doubt exists whether a peacetime substitution of wheeled for tracked vehicles would be cost effective. It would be very expensive to develop surrogate vehicles which carry weapon systems. Mission equipment represents a significant percentage of the procurement cost of a combat vehicle and this equipment would have to be carried over to the surrogate vehicle if it was going to be a realistic training platform.

There was a general consensus that development of advanced simulators (e.g., like the current Unit Conduct of Fire Trainer (UCOFT) or the proposed SIMNET systems) would be a more productive course of action than attempting to develop surrogate wheeled vehicles for peacetime use. A simulator offers the crew an opportunity to train on equipment that is laid out and responds exactly like the actual combat vehicles and can expose the crew to a greater variety of operational situations in their allotted training time. The proposed simulator networked systems will offer the opportunity for force-on-force training with crews in one group of simulators pitted against crews in other simulators at different locations. Additionally, small scale systems like the Videodisk Gunnery Simulator (VIGS) offer training simulation systems that can be implemented at the company level for relatively modest cost.

SUBSTITUTE WHEELS FOR TRACKS DURING PEACETIME

- DOES NOT APPEAR TO BE A DESIRABLE COURSE OF ACTION

- LIMITED APPLICATION
  - MANEUVER TRAINING
  - CURRENTLY BEING DONE TO A LIMITED DEGREE

- PROBABLY WOULD RESULT IN REDUCED READINESS
  - TRAINING ON DIFFERENT EQUIPMENT
  - LEARNING CURVE DURING MOBILIZATION
  - "TRAIN LIKE WE FIGHT AND FIGHT LIKE WE TRAIN"

- DOUBTFUL IF COST EFFECTIVE
  - NEED TO MAINTAIN TWO FLEETS OF VEHICLES
  - WOULD HAVE TO TRAIN ON ACTUAL EQUIPMENT FOR ARTEP ANYWAY
  - SURROGATE VEHICLES WITH WEAPON SYSTEMS WOULD BE EXPENSIVE TO DEVELOP AND MAINTAIN

- DEVELOPMENT OF SIMULATORS APPEARS TO BE BETTER COURSE OF ACTION

HEADQUARTERS
TRADOC

SLIDE 10 - SHORT DISTANCE MOBILITY ENHANCEMENTS

SELF-EXPLANATORY

DO WE NEED TO PROVIDE SOME SHORT DISTANCE MOBILITY ENHANCEMENTS FOR WHEELED VEHICLES?

HEADQUARTERS
TRADOC

SLIDE 11 - SHORT DISTANCE MOBILITY ENHANCEMENTS

In the short term, there are a few areas where improvements to wheeled vehicle off-road mobility can be achieved with minimum investment. The first is through the expanded use of tire chains. Tire chains are extremely effective in increasing traction on packed snow or ice and will bring about a 10 to 20 percent increase in a wheeled vehicle's depth tolerance in shallow snow. Additionally, the use of tire chains in wet/slippery off-road conditions brings about a five percent reduction in VCI with a corresponding increase in wet/slippery soil mobility.

Operationally, the reduction of tire pressure by 50% will result in a 10% reduction in VCI which will result in a considerable mobility enhancement in soft-soil or sand. The drawback to manual deflation of tires is that they must be reinflated to correct pressure before any high speed driving is done or the tires will be damaged.

Another area that has proven successful is in the use of various expedient surfacing materials (e.g., sand grids). These products are effective at providing a temporary improvement in surface strength to marginal terrain. The major drawback to the use of expedient surfacing materials is the logistics burden associated with storing and transporting and the time penalty required for emplacement.

SHORT DISTANCE MOBILITY ENHANCEMENTS
NEAR-TERM IMPROVEMENTS

- EQUIPMENT
  - TIRE CHAINS
    - 5 PERCENT REDUCTION IN VCI
    - 100 % INCREASE IN TRACTION ON ICE AND HARD SNOW
    - 10 - 20 % INCREASE IN SHALLOW SNOW DEPTH TOLERANCE
- OPERATIONAL
  - EMERGENCY DEFLATION OF TIRES
    - 10 % REDUCTION IN VCI
    - 6 - 9 % INCREASE IN SOFT-SAND MOBILITY
- EXPEDIENT SURFACING
  - LIGHT EGRESS MATTING
  - SAND GRID

HEADQUARTERS
TRADOC

SLIDE 12 - LONG-TERM IMPROVEMENTS

With respect to long-term mobility improvements for wheeled vehicles, Central Tire Inflation (CTI) systems are proven technology that offer considerable promise as a mobility enhancer. CTI systems offer the vehicle operator the capability to deflate and reinflate the vehicle's tires without having to leave the cab or stop the vehicle. Additionally, CTI systems have the capability to overcome small tire punctures by maintaining tire pressure which will allow the vehicle to continue to operate. All Warsaw Pact countries use CTI systems on their wheeled combat vehicles.

Another area where off-road mobility can be enhanced is in improved tire technology, both in tread designs and materials. Additionally, the use of single rather than dual tires would improve off-road mobility. Single tires offer a greater ground contact area and corresponding lower ground pressure for a given tire volume.

Operationally, wheeled vehicle mobility can be enhanced by providing higher levels of engineer support (e.g., earth moving equipment or portable bridges) to overcome terrain obstacles.

SHORT DISTANCE MOBILITY ENHANCEMENTS
LONG-TERM IMPROVEMENTS

- EQUIPMENT
  - CENTRAL TIRE INFLATION SYSTEMS
    - 10 % REDUCTION IN VCI
    - AUTOMATIC REINFLATION
    - IMPROVED SOFT-SOIL AND SAND MOBILITY
  - IMPROVED TIRE TECHNOLOGY
    - MATERIALS
    - TYPE OF CONSTRUCTION
    - TREAD DESIGNS
- OPERATIONAL
  - CONTINUOUS ENGINEER SUPPORT
    - M9 ACE
    - LIGHT ASSAULT BRIDGE

HEADQUARTERS
TRADOC

SLIDE 13 - HALF-TRACKED VEHICLE CONCEPT

SELF-EXPLANATORY

DOES THE HALF-TRACKED VEHICLE CONCEPT HAVE SUFFICIENT MERIT TO WARRANT RDT&E?

HEADQUARTERS
TRADOC

SLIDE 14 - HALF-TRACKED VEHICLE CONCEPT

We solicited input from both WES and TACOM on this question and they were in agreement that it would not be desirable to pursue this vehicle configuration. The half-tracked vehicle was a World War II wartime expedient. Eighteen different version were produced during the war years. The half-tracked vehicle offered superior off-road mobility to wheeled vehicles of its day; though, at the expense of road speed, fuel efficiency, mechanical complexity and reliability. A modern 6x6 or 8x8 high-mobility wheeled vehicle offers comparable off-road mobility without having to make any of the trade-offs that are inherent in the half-track configuration. Half-tracks were phased out of production in the early fifties and are not being produced anywhere in the world today. The few countries that still use half-tracks are using them primarily because they do not have the resources to replace them with modern vehicles. A few manufacturers have attempted to revive the vehicle configuration, but to date, none have been successful.

HALF-TRACKED VEHICLE CONCEPT

- NOT DESIRABLE TO PURSUE THIS TYPE OF VEHICLE
- WORLD WAR II TECHNOLOGY
  - WARTIME EXPEDIENT
  - SUPERIOR CROSS COUNTRY MOBILITY TO WHEELED VEHICLES OF ITS DAY
  - 18 DIFFERENT VERSIONS
  - VCI = 31
- MODERN 6 X 6 OR 8 X 8 WHEELED VEHICLE
  - BETTER RIDE CHARACTERISTICS
  - COMPARABLE OFF-ROAD MOBILITY
  - HIGHER ROAD SPEEDS
  - BETTER FUEL EFFICIENCY
  - BETTER RELIABILITY AND MAINTAINABILITY CHARACTERISTICS
- NO HALF-TRACKED VEHICLES CURRENTLY IN PRODUCTION

HEADQUARTERS
TRADOC

SLIDE 15 - IMPORTANCE OF TERRAIN

SELF-EXPLANATORY

WHAT IS THE RELATIVE IMPORTANCE OF TERRAIN CONSIDERATIONS, IN COMPARISON TO OTHER FACTORS, FOR THE CBT, CS, AND CSS VEHICLE MISSION AREAS?

HEADQUARTERS
TRADOC

SLIDE 16 - IMPORTANCE OF TERRAIN

The importance of terrain is more a function of where on the battlefield the vehicle mission role is to be performed, rather than whether the function is Combat, Combat Support or Combat Service Support. Within the brigade tactical area, it is extremely important that all vehicles be capable of negotiating the terrain so as not to impede the pace of operations. The combat elements should not be constrained by lack of mobility in their support forces. Beyond the brigade tactical area, off-road mobility is not as critical. Vehicles are operating primarily on roads and usually there is time to plan a route so as to avoid most terrain obstacles.

This concludes the answers to the specific questions that were deleted from the main Wheeled Versus Tracked Vehicle Study briefing.

IMPORTANCE OF TERRAIN

- BRIGADE TACTICAL AREA (WITHIN 30 KM OF FLOT)
  - MAIN BATTLE AREA
  - VEHICLES OPERATE OVER RELATIVELY SHORT DISTANCES
  - FLUID OPERATIONS
  - PRIMARILY A CBT AND CS AREA OF OPERATIONS
  - CROSS COUNTRY MOBILITY IS A PRIMARY CONSIDERATION
- SUPPORT AREAS (BEYOND 30 KM OF FLOT)
  - MORE STABLE OPERATIONS
  - VEHICLES OPERATE OVER LONGER DISTANCES AND PRIMARILY ON ROADS
  - TIME TO MOVE AROUND MOST TERRAIN OBSTACLES
  - PRIMARILY A CSS AREA OF OPERATIONS
  - CROSS COUNTRY MOBILITY IS A SECONDARY CONSIDERATION

HEADQUARTERS
TRADOC

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Chapter 3

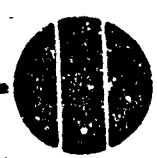
Backup Slides

BACKUP SLIDE 1 - DEFINITIONS

Depicted here are definitions of the components that go into developing the Rating Cone Index (RCI) and Vehicle Cone Index (VCI) indices used by the US Army Corps of Engineers' Waterways Experiment Station (WES). The basic component of the RCI is the Cone Index (CI) that is obtained with a cone penetrometer for a given area of ground at a given point in time. Numerous CI ratings are obtained for a given area of terrain and statistically grouped to produce an average CI for that area of terrain. The Remolding Index (RI) is collected in conjunction with the CI and is the ratio of the strength the soil retains after it is compacted to the original soil strength. As with the CI, numerous RI ratings are averaged together to come up with an average RI rating that corresponds with the average CI rating for a given area of terrain. The RCI for that area of terrain is then obtained by multiplying the average CI and RI ratings together. The VCI, which is normally shown with a subscript, is the minimum RCI soil strength required to support the subscripted number of passes of vehicle. It is important to note that the RCI is a characteristic of terrain that varies with the seasons and the VCI is a fixed characteristic of a vehicle.

DEFINITIONS

- CONE INDEX (CI) - INDEX OF THE SHEARING RESISTANCE OF A SOIL MEDIUM OBTAINED WITH A CONE PENETROMETER AT A GIVEN PLACE AND TIME
- REMOLDING INDEX (RI) - RATIO OF THE PORTION OF ORIGINAL STRENGTH THE SOIL WILL RETAIN AFTER IT IS COMPACTED
- RATING CONE INDEX (RCI) - PRODUCT OF THE AVERAGE CI AND RI FOR A GIVEN AREA OF GROUND UNDER SPECIFIED WEATHER CONDITIONS
- VEHICLE CONE INDEX (VCI_N) - THE MINIMUM RCI THAT WILL PERMIT THE NUMBER OF VEHICLE PASSES SPECIFIED BY THE SUBSCRIPT "N"



HEADQUARTERS
TRADOC

BACKUP SLIDE 2 - WESTERN NATIONS - UK

Philosophically, the British Army has a strong bias towards tracked vehicles and makes limited use of wheeled armored vehicles as scouts, armored personnel carriers and internal security vehicles. The great majority of British mechanized infantry, including all units supporting tanks, are carried in tracked armored vehicles.

Thus far, the British Army has not used wheeled armored vehicles for troop transport except in Northern Ireland, but budget limitations have forced the recent purchase of 1000 AT105 Saxon wheeled armored personnel carriers. The Saxons are not being procured to replace existing tracked vehicles. They are being procured to provide armor protection for vehicle roles formerly supported by unarmored trucks. Primarily, the Saxons are intended to function in the role of a battlefield taxi to provide limited protection to the occupants while they are moving about the battlefield. The occupants will dismount when they are engaged in combat operations.

The Scorpion family of light tracked vehicles provides approximately one-third of the British Army's reconnaissance vehicles as well as a number of command and control, maintenance and armored ambulance vehicles, but the majority of the British Army's reconnaissance vehicles are the wheeled Fox. The Fox is the latest in a long line of British armored cars that have been used in the scout role.

The future direction of the British Army with respect to wheeled and tracked vehicles is not clear. Though they have a strong preference for tracked vehicles, economic considerations may force an expanded use of wheeled armor.

WESTERN NATIONS

- UNITED KINGDOM
  - LIMITED USER OF WHEELED ARMORED VEHICLES
    - SCOUTS
    - ARMORED PERSONNEL CARRIERS
    - INTERNAL SECURITY VEHICLES
  - EXPANDING WHEELED ARMORED VEHICLE FLEET IN SUPPORT ROLES

HEADQUARTERS
TRADOC

BACKUP SLIDE 3 - WESTERN NATIONS (CONT) - FRG

In the West German Army, fewer than 15 percent of the light armored vehicles are wheeled. The West Germans restrict the use of wheeled armored vehicles to a complementary reconnaissance vehicle and various support roles.

The West Germans developed the wheeled Luchs to fill the need for a fast, reliable, reconnaissance vehicle able to operate for long distances on roads and yet retain a high degree of off-road mobility and an amphibious capability. Because of rather demanding requirements for mobility and protection, the Luchs ended up with most of the complexity, weight, and cost of a tracked vehicle. It is the world's heaviest and best protected wheeled reconnaissance vehicle and, at least automotively, by far the most complex. The Luchs has excellent off-road mobility characteristics for an vehicle of its weight class but achieves freedom of movement at the expense of tremendous mechanical complexity.

The only other wheeled armored vehicle in the West German Army is the utility TPZ (Transportpanzer -- armored transport) family. The TPZ is essentially an armored hull with a truck drive train and was designed as a support vehicle. Nearly 1000 TPZs have been produced and are used for a variety of support functions including: command and communications, battlefield resupply, NBC reconnaissance, ground surveillance radar, electronic warfare, and engineer support.

In the mid 1960s, the West Germans developed the UR-416. The vehicle was merely a lightly armored shell installed on a truck chassis and was used as an internal security vehicle, assigned to police forces rather than the military. The success of the UR-416 led to the development of the more sophisticated UR-425 Condor using components from newer trucks in the Unimog family. Like its predecessor, the Condor will be used by the police forces rather than the military.

In general, the West Germans see wheeled armored vehicles as complementary systems to tracked vehicles and exploit the advantages of wheeled armor for the mission roles where it can be most effective. The West German have achieved what appears to them an optimal mix of wheeled and tracked light armored vehicles. If there is a trend in the West German Army, it is towards the expanded use of tracks. This is evidenced by their recent decision to procure approximately 330 of the light tracked Porsche Wiesels. The Wiesel is somewhat of an anomaly for a light armored vehicle since it is in a weight class (combat loaded weight of approximately 3 tons) that is almost the exclusive domain of wheeled vehicles. The vehicle is expensive but apparently, the West Germans feel that the added operational utility of the tracked configuration is worth the additional expense.

WESTERN NATIONS (CONT)

- FEDERAL REPUBLIC OF GERMANY
  - LIMITED USER OF WHEELED ARMORED VEHICLES
    - SCOUTS
    - SUPPORT VEHICLES
    - INTERNAL SECURITY VEHICLES
  - NO TRENDS TOWARDS EXPANDED USE OF WHEELED ARMORED VEHICLES

HEADQUARTERS TRADOC

BACKUP SLIDE 4 - WESTERN NATIONS (CONT) - FRANCE

France is Western Europe's largest user of wheeled armored vehicles. French armored divisions have roughly equal numbers of tanks, light tracked vehicles and wheeled armored vehicles. The maneuver elements of France's heavy divisions contain only tracked vehicles while the wheeled armored vehicles, assorted models of the VAB (Vehicle de l'Avant Blinde -- armored vehicle for forward areas) are found in various support units including the anti-tank guided missile (ATGM) company. French infantry divisions, (including the light infantry divisions with the rapid deployment mission and the single alpine division) are entirely equipped with wheeled armored vehicles. These are primarily variants of the general purpose VAB family but, also include a small number of AMX-10RC or ERC-90 wheeled reconnaissance vehicles.

In general, the French equip units in direct support of what they call the "Tank-Helicopter Team" with tracked vehicles. For all other purposes, the French prefer wheeled armored vehicles. The French preference for wheeled armored vehicles appears to motivated not only by cost considerations, but by the somewhat unique rapid deployment requirements that have grown out of France's former colonial possessions. The French feel that wheeled armored vehicles are ideally suited to the rapid deployment role. Wheeled armored vehicles can self-deploy to ports of embarkation and following debarkation in or near the contingency area, can road march for considerable distances with very little wear and tear on the vehicle or the crew. It is not practical to operate tracked vehicles in this manner.

The French appear to have reached what they consider an optimal mix of wheeled and tracked light armored vehicles and do not appear to be making any efforts to move away from their current force mix.

WESTERN NATIONS (CONT)

- FRANCE
  - MOST EXTENSIVE USE OF WHEELED ARMORED VEHICLES BY A WESTERN NATION
    - LIGHT MOTORIZED FORCES
    - SCOUTS
    - SUPPORT VEHICLES
  - APPEARS TO HAVE REACHED WHAT THEY CONSIDER AN OPTIMAL FLEET MIX

HEADQUARTERS
TRADOC

BACKUP SLIDE 5 - WESTERN NATIONS (CONT) - CANADA

The Canadians started using wheeled armored vehicles with the introduction of the Armored Vehicle General Purpose (AVGP) family. The bulk of Canada's tracked vehicle force is assigned to NATO and stationed in Germany. Home defense and internal security functions are assigned to wheeled armored vehicles because of their lower operating and support costs and the ability to rapidly self-deploy over the highway system.

The Canadian AVGP family includes the Grizzly armored personnel carrier, the Cougar fire support vehicle, and the Huskey armored maintenance and recovery vehicle. The AVGP family has an extremely high power to weight ratio (26 hp/ton) but the tires are small and soft-soil mobility suffers. The Grizzly has proven to be a capable and reliable tactical vehicle and is currently being used with the Canadian AMF(L) Battalion Group and with the Canadian Air/Sea Transportable (CAST) Brigade for deployment with the Canadian UN peacekeeping forces in Cyprus. The Cougar variant of the AVGP family uses the turret and 76mm main gun of the British Scorpion reconnaissance vehicle. An unusual aspect of the Canadian rationale for the purchase of the Cougar was the need for an inexpensive tank trainer. The Canadians are satisfied that a significant portion of tank skills and tactics can be taught using wheeled armored vehicles. The Cougar has been evaluated as a reconnaissance vehicle with the Canadian forces in Germany, but the vehicle did not meet the operational requirements of the mission role. At present, the Cougar is used only as a surrogate tank trainer.

In the future, the Canadians will probably be expanding their use of wheeled armor. They are satisfied with the performance of the AVGP family and the operating and support cost savings have been better than expected. The Canadians are presently looking at anti-tank, command and control, air defense (gun and missile) and general fire support (90mm gun and rocket) variants of the AVGP family.

WESTERN NATIONS (CONT)

- CANADA
  - LIMITED USER OF WHEELED ARMORED VEHICLES
    - ARMORED PERSONNEL CARRIERS
    - SUPPORT VEHICLES
    - SURROGATE TANK TRAINERS
  - GENERAL TREND TOWARDS EXPANDING WHEELED ARMORED VEHICLE FLEET

HEADQUARTERS
TRADOC

BACKUP SLIDE 6 - WESTERN NATIONS (CONT) - NETHERLANDS & BELGIUM

The Netherlands have been using the wheeled DAF YP-408 armored personnel carrier for a number of years. In 1982, they undertook a study to select a replacement APC for their aging fleet of wheeled YP-408s. As a going-in position, they stated a requirement for the replacement vehicle to mount a turreted gun of at least 25mm, provide space for a complete infantry squad, a driver and a gunner. Following a rigorous analysis of alternative vehicles, the Dutch decided upon the tracked YPR-765 (a product improved version of the FMC 113) as a replacement for their fleet of wheeled APCs. This decision was made in spite of a documented 25 percent reduction in operating and support costs associated with the wheeled configuration. The Dutch appear to be moving in the direction of a totally tracked force.

Belgian industry produces both wheeled and tracked light armored vehicles, but the Belgian Army does not use any wheeled armor. The decision to exclusively procure tracked vehicles was made following a series of mobility and endurance tests in which the wheeled candidates were judged superior in durability but poorer in operational mobility. In the end, the military's operational mobility requirements won out over the economic and internal political considerations favoring purchase of the wheeled alternatives. The Belgians have recently signed contracts to replace their aging fleet of M74 and AMX-13 Armored Personnel Carriers with 514 of the Dutch YPR-765 Infantry Fighting Vehicles and 525 M113A1 Armored Personnel Carriers. The Belgians appear to be satisfied with their tracked force and do not have any plans to introduce wheeled armored vehicles.

WESTERN NATIONS (CONT)

- NETHERLANDS
  - LIMITED USER OF WHEELED ARMORED VEHICLES
    - ARMORED PERSONNEL CARRIERS
  - REPLACING WHEELED ARMORED PERSONNEL CARRIER FLEET WITH TRACKS
- BELGIUM
  - PRODUCES BUT DOES NOT USE WHEELED ARMORED VEHICLES
  - NO PLANS TO EXPAND USE OF WHEELED ARMORED VEHICLES

HEADQUARTERS
TRADOC

BACKUP SLIDE 7 - WESTERN NATIONS (CONT) - ISRAEL, ITALY & JAPAN

The Israeli Army has a strong preference for tracked vehicles. Out of approximately 11,500 light armored vehicles in the Israeli Army, less than 700 are wheeled and these are principally captured vehicles of Soviet or Egyptian manufacture.

Israel produces two wheeled armored vehicles, the rather primitive Shoet (a copy of the Soviet BTR-152) and the RBY. The RBY is a small open-topped 4 X 4 wheeled armored vehicle of somewhat unusual design. The open-top confiquration was chosen because it gives the troops maximum visibility and allows them to fire their individual weapons in any direction while mounted. Protection against mines was a major design priority with the RBY and the vehicle is unusual in that it carries its thickest armor on its belly. Additionally, the axles have been placed at the extreme ends of the vehicle in order to maximize the distance between the crew and a mine detonated by a wheel. The RBY is used exclusively by the Israeli border guards in an internal security role. Israel also has a substantial number of US manufactured half-tracked vehicles in its inventory, but it is likely that these vehicles will be replaced by full-tracked vehicles when they reach the end of their useful life. They are presently retained as an economic expedient.

The Israeli Army has a strong preference for tracked vehicles and there are no indications that they plan to expand their current limited roles for wheeled armored vehicles in the near future.

Italy and Japan both produce wheeled armored vehicles but neither country uses the vehicles in their armies. The vehicles produced are exclusively for the export market. Both countries are currently carrying out limited experiments with wheeled armor and it is possible that they will introduce wheeled armored vehicles into their military inventories if the current experiments prove successful.

WESTERN NATIONS (CONT)

- ISRAEL
  - LIMITED USER OF WHEELED ARMORED VEHICLES
    - INTERNAL SECURITY VEHICLES
  - NO PLANS TO EXPAND USE OF WHEELED ARMORED VEHICLES
- ITALY & JAPAN
  - PRODUCE BUT DO NOT USE WHEELED ARMORED VEHICLES
  - EXPERIMENTING WITH USING WHEELED ARMORED VEHICLES

HEADQUARTERS
TRADOC

BACKUP SLIDE 8 - EUROPEAN COMMUNIST COUNTRIES - SOVIET UNION

In general, the Soviet Union makes far heavier use of wheeled armored vehicles than any of its potential adversaries in NATO. France is the only West European country that even approaches the Soviet Union's commitment to wheeled armored vehicles. The Soviet Union uses wheeled armored vehicles for a multitude of roles including: armored personnel carriers, reconnaissance vehicles in both tank and rifle divisions, command and communications, forward air controllers, anti-tank missile carriers, anti-aircraft missile carriers and NBC reconnaissance. It is important to note that the Soviets have had an "everything must be under armor" philosophy for some time and all Soviet divisions are mechanized. With the 1967 introduction of the tracked BMP, the Soviets initiated a program to re-equip one motorized rifle regiment in each motorized rifle division with the new light tracked vehicle. With this equipment change, the proportion of Soviet infantry carried in tracked armored vehicles has grown steadily over the years and at present stands at approximately 50 percent.

It is probable that the Soviets will continue to expand their use of both wheeled and tracked light armored vehicles. Though, the Soviets show a clear preference for the tracked vehicle as a platform for mounted combat. It is probable that if the Soviets deviate from their current mix of wheeled and tracked light armored vehicles, it will be in the direction of replacing wheeled armored vehicles with tracks.

EUROPEAN COMMUNIST COUNTRIES

- SOVIET UNION
  - EXTENSIVE USER OF WHEELED ARMORED VEHICLES
    - MOTORIZED DIVISIONS
    - SCOUTS
    - SUPPORT VEHICLES
  - APPEARS TO HAVE REACHED WHAT THEY CONSIDER AN OPTIMAL MIX

HEADQUARTERS TRADOC

BACKUP SLIDE 9 - EUROPEAN COMMUNIST COUNTRIES (CONT)

The non-Soviet Warsaw Pact countries have structured their forces around the Soviet example and make extensive use of wheeled armored vehicles. As they acquire more tracked BMPs, they appear to be following the Soviet example and upgrading their tactical forces by replacing wheeled APCs with tracked IFVs. It is probable that this trend will continue.

Yugoslavia has a domestic wheeled and tracked armored v[illegible]le industry, but at present, makes only limited use of wheeled armored vehicles. The Yugoslavian Army restricts wheeled armor to anti-tank and anti-aircraft roles. They do not use wheeled armored vehicles for armored personnel carriers. This is a somewhat unique organizational philosophy for a European communist country. All of the Warsaw Pact countries use wheeled armored vehicles as their primary armored personnel carriers and restrict light tracked vehicles to the Infantry Fighting Vehicle role. It appears that the Yugoslavian Army looks upon wheeled armored vehicles as special purpose vehicles and believes that they are only suitable for specific roles.

In the future, if Yugoslavia expands its use of wheeled armored vehicles, it is probable that the expansion will come in mission roles formerly supported by unarmored trucks rather than as a replacement for tracked vehicles.

EUROPEAN COMMUNIST COUNTRIES (CONT)

- CZECH, GDR, POLAND, HUNGARY, BULGARIA AND ROMANIA
  - EXTENSIVE USERS OF WHEELED ARMORED VEHICLES
  - GENERAL TREND TO INCREASE THE CAPABILITIES OF MOTORIZED FORCES BY INTRODUCING MORE TRACKED VEHICLES

- YUGOSLAVIA
  - VERY LIMITED USER OF WHEELED ARMORED VEHICLES
    - SPECIAL PURPOSE VEHICLES
  - DOES NOT APPEAR TO BE EXPANDING WHEELED ARMORED VEHICLE FLEETS

HEADQUARTERS TRADOC

BACKUP SLIDE 10 - NON-ALIGNED NATIONS - BRAZIL & SOUTH AFRICA

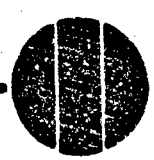
Brazil is the free world's largest producer of wheeled armored vehicles. Their two major designs are the Engesa EE-9 Cascavel reconnaissance vehicle and the EE-11 Urutu armored personnel carrier. Brazil has made extensive sales of the Engesa vehicles throughout the third world. Brazil does not currently have a domestic light tracked vehicle production capability and the decision to buy wheeled armored vehicles appears to have been motivated as much by economic concerns as it was by operational considerations.

It is probable that Brazil will continue to expand its domestic use of wheeled armored vehicles and will replace its light tracked vehicle fleet with wheeled armor as the tracks reach the end of their useful life.

South Africa was forced into weapons self sufficiency by a trade embargo. They found it easier to manufacture wheeled rather than tracked light armored vehicles and for the most part, wheeled armor provides all the mobility necessary for South Africa terrain. South Africa's standard Infantry Fighting Vehicle (IFV) is the 19 ton Ratel. The term IFV is normally reserved for tracked vehicles, but the Ratel has most of the attributes of an IFV. Standard main armament is a 20mm automatic cannon, but two other models are also produced, one with a 90mm cannon and the other with a 60mm mortar. Additionally, a logistics version of the vehicle has been developed. South Africa appears to be content with its present wheeled force and does not have any plans to expand their use of tracked vehicles.

NON-ALIGNED COUNTRIES

- BRAZIL
  - FREE WORLD'S LARGEST PRODUCER OF WHEELED ARMORED VEHICLES
  - EXPANDING WHEELED ARMORED VEHICLE FLEET
- SOUTH AFRICA
  - EXTENSIVE USER OF WHEELED ARMORED VEHICLES
  - NO PLANS TO EXPAND USE OF TRACKED VEHICLES



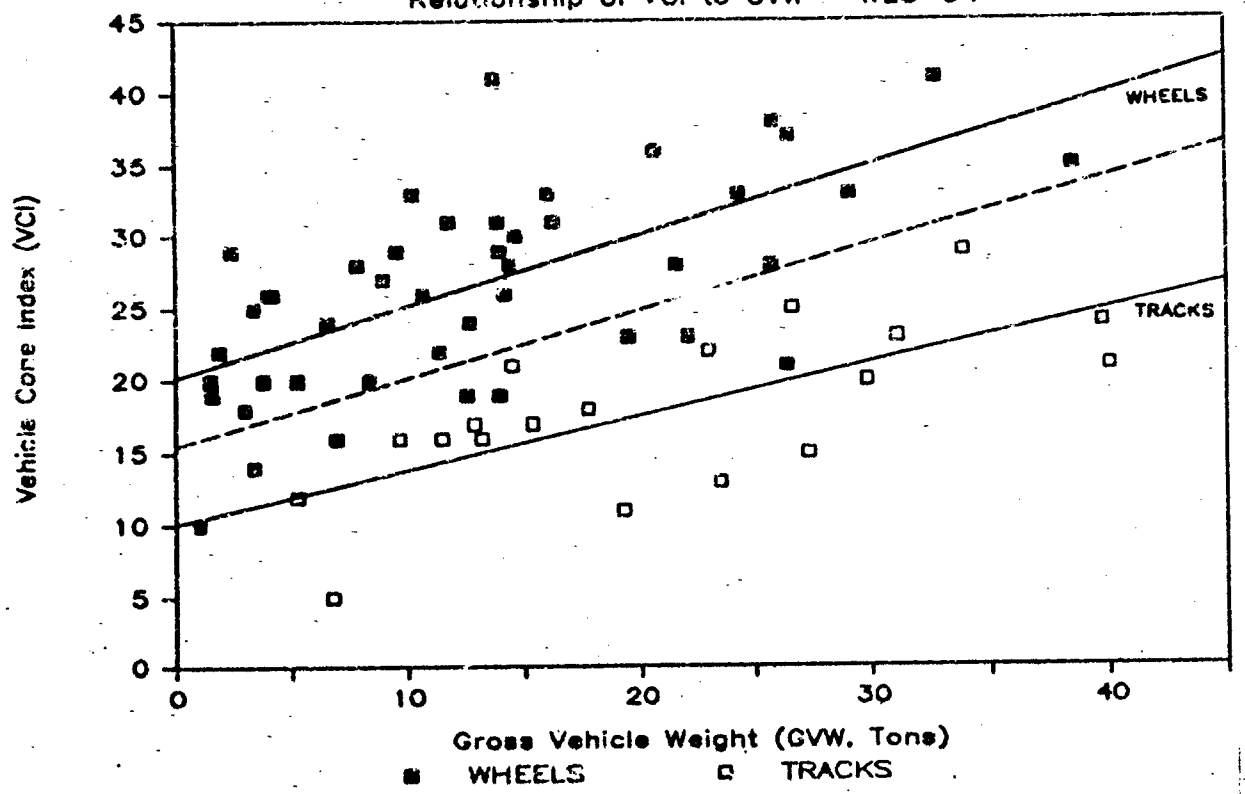
HEADQUARTERS
TRADOC

BACKUP SLIDE 11 - SOFT-SOIL MOBILITY - REGRESSION ANALYSIS

The two solid lines depicted here are regression lines of Vehicle Cone Index (VCI) versus gross vehicle weight (GVW) for a group of 45 high-mobility wheeled vehicles and a group of 23 tracked vehicles. In general, the lower a vehicle's VCI, the greater the vehicle's overall terrain mobility. A VCI of 25 will give a vehicle about 80 percent terrain mobility in a temperate environment during the wet season. If we use this criteria, we see that the wheeled vehicle regression line crosses the VCI=25 level at approximately the 10 ton GVW level. Conversely, tracked vehicles are almost by definition below the VCI=25 level. This holds true for even 60 ton main battle tanks. The M1 main battle tank carries a VCI rating of 23 while the older M60A3 carries a VCI rating of 20. Once a wheeled vehicle goes over 10 tons GVW, it requires very good design practice and a 6X6 or 8X8 automotive configuration to keep the VCI below the 25 level.

The broken line is a regression line of the best 19 wheeled vehicles in the group of 45. We see that this regression line will cross the VCI=25 level at about 20 tons GVW. Above 20 tons GVW, high-mobility wheeled vehicles tend to be very large and have a high degree of mechanical sophistication (e.g., a 10X10 articulated vehicle or the West German Luchs). For this reason, 20 tons GVW is a practical upper weight limit for high-mobility military wheeled vehicles.

WHEELED VS TRACKED VEHICLES

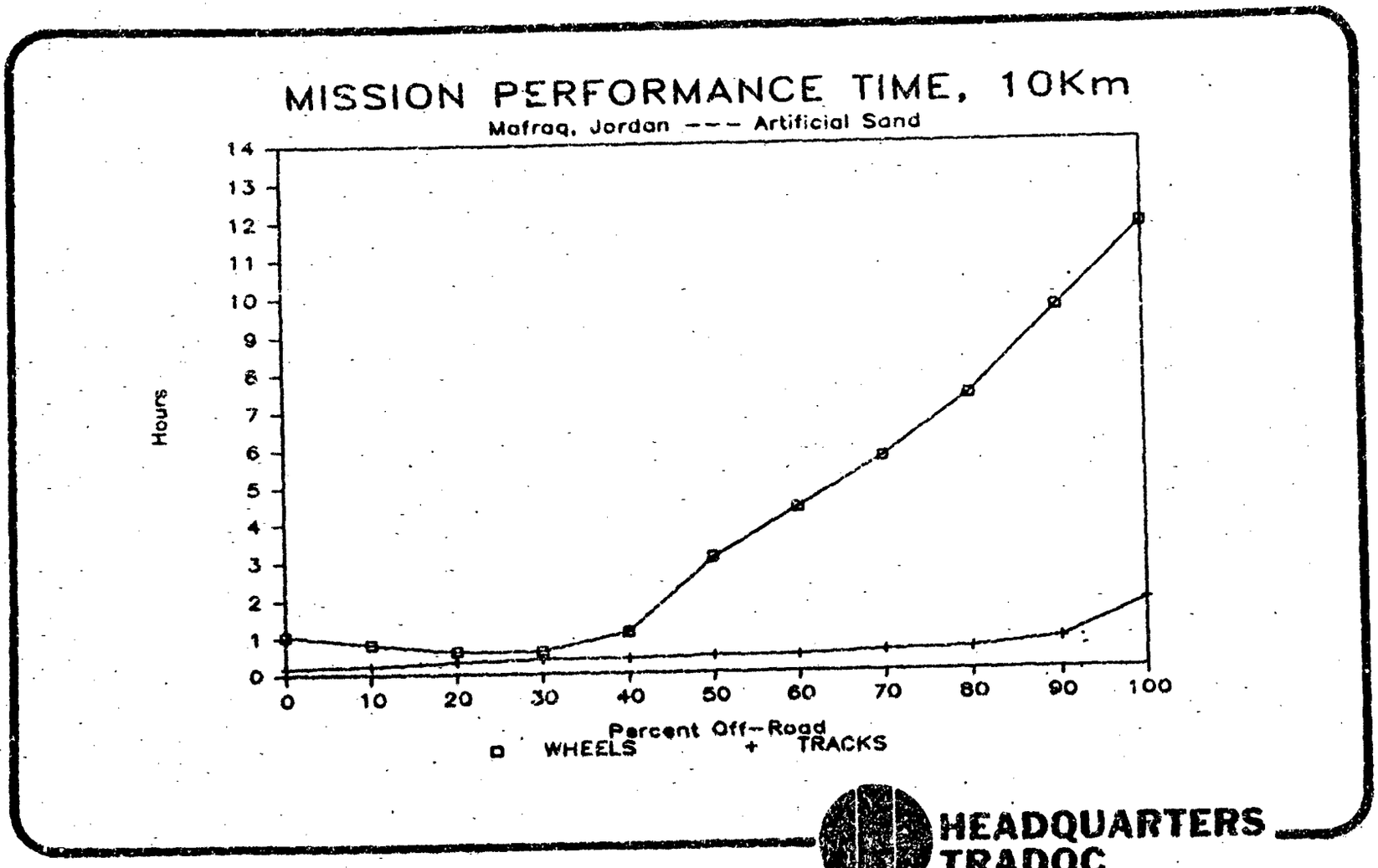


HEADQUARTERS
TRADOC

BACKUP SLIDE 12 - MISSION PERFORMANCE TIME - ARTIFICIAL SAND CONDITION

The Mission Performance Times analysis is explained on slide 27 of the main briefing. In WES's generation of mission performance times, as an excursion analysis, the terrain of Mafraq, Jordan, was artificially changed to soft-sand to compare the performance of wheeled and tracked vehicles. This was done as an expedient because WES does not possess a digitized terrain quadrant for soft-sand terrain. The general topology of the Mafraq terrain was retained, only the soil characteristics were changed.

In looking at the mission performance times achieved by the groups of wheeled and tracked vehicles, we see that the wheels suffered a considerable mobility disadvantage in the time that it takes to perform a 10km mission. In the 100 percent off-road condition, the time difference between the wheeled and tracked vehicles is approximately 10 hours.


MISSION PERFORMANCE TIME, 10Km
Mafraq, Jordan --- Artificial Sand
Hours
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
Percent Off-Road
WHEELS
TRACKS
HEADQUARTERS
TRADOC

BACKUP SLIDE 13 - GAP CROSSING - 1979 WACROSS STUDY - VEHICLES

In 1979, WES performed the WACROSS study which was an analysis of gap crossing in the temperate Lauterbach, FRG, and the arid Mafraq, Jordan, environments. The analysis used this group of wheeled and tracked vehicles as the candidate vehicles for the study. The analysis was performed using the Army Mobility Model.

1979 WES WACROSS STUDY

WHEELED VEHICLES	TRACKED VEHICLES
M151A2	M548E1
M861	M113A2
M35A2	XM723
M813	M551
M656	M60A1
M520E1	
M125E1	
TD9M1	

HEADQUARTERS
TRADOC

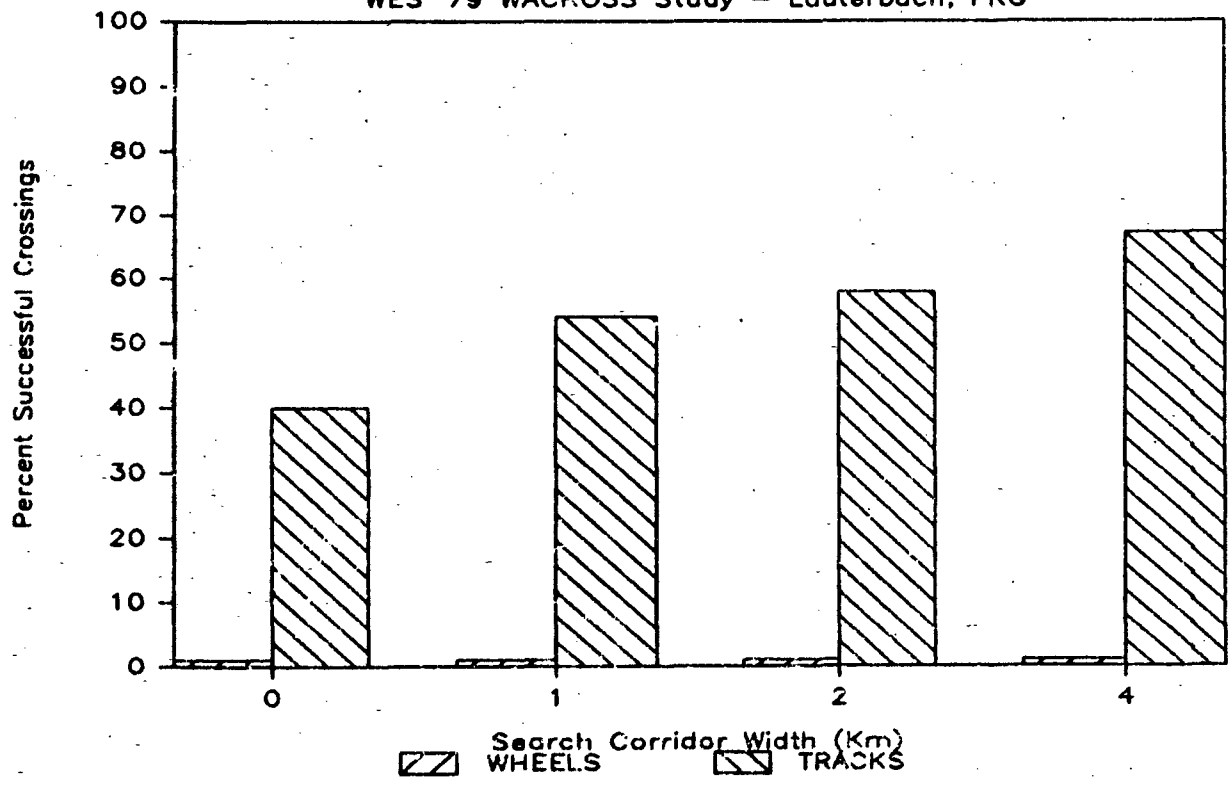
BACKUP SLIDE 14 - GAP CROSSING - LAUTERBACH, FRG - 1979 WACROSS STUDY

In the WACROSS study, WES simulated a search corridor width that would be evaluated in an attempt to find a path around the gap if it was not passable when initially encountered. The results depicted here show the base case (search corridor width 0) where the vehicle attempted to cross the gap without deviating from its original path and three excursions where the vehicle moved laterally along the gap to attempt a crossing. A search corridor width of one kilometer means that the terrain was evaluated for one-half kilometer on either side of the vehicle's original path. Similarly for search corridor widths of two and four kilometers. On average, gaps are encountered every three to five kilometers in the Lauterbach area of central Europe.

As can be seen from the chart, in the Lauterbach environment, wheeled vehicles were successful in negotiating gaps only one percent of the time. This compares with a success rate of 40 to 67 percent for the tracked vehicles.

GAP CROSSING

WES '79 WACROSS Study – Lauterbach, FRG



HEADQUARTERS
TRADOC

BACKUP SLIDE 15 - GAP CROSSING - LAUTERBACH, FRG - DENIAL FACTORS

The factors that contributed to the poor showing by the wheeled vehicles in the Lauterbach environment are depicted here. Note the percentages have been reversed from that shown on the previous graph. We are now looking at the reasons for denial.

The primary areas where wheeled vehicles failed to negotiate the gaps were in bank clearance (belly hangup) and egress traction (soft-soil mobility). The reasons for these problems are intrinsic in the wheeled configuration and difficult to overcome and still retain the on-road speed and reliability advantages that wheeled vehicles normally enjoy.

1979 WES WACROSS STUDY
LAUTERBACH, FRG -- PERCENT UNSUCCESSFUL CROSSINGS

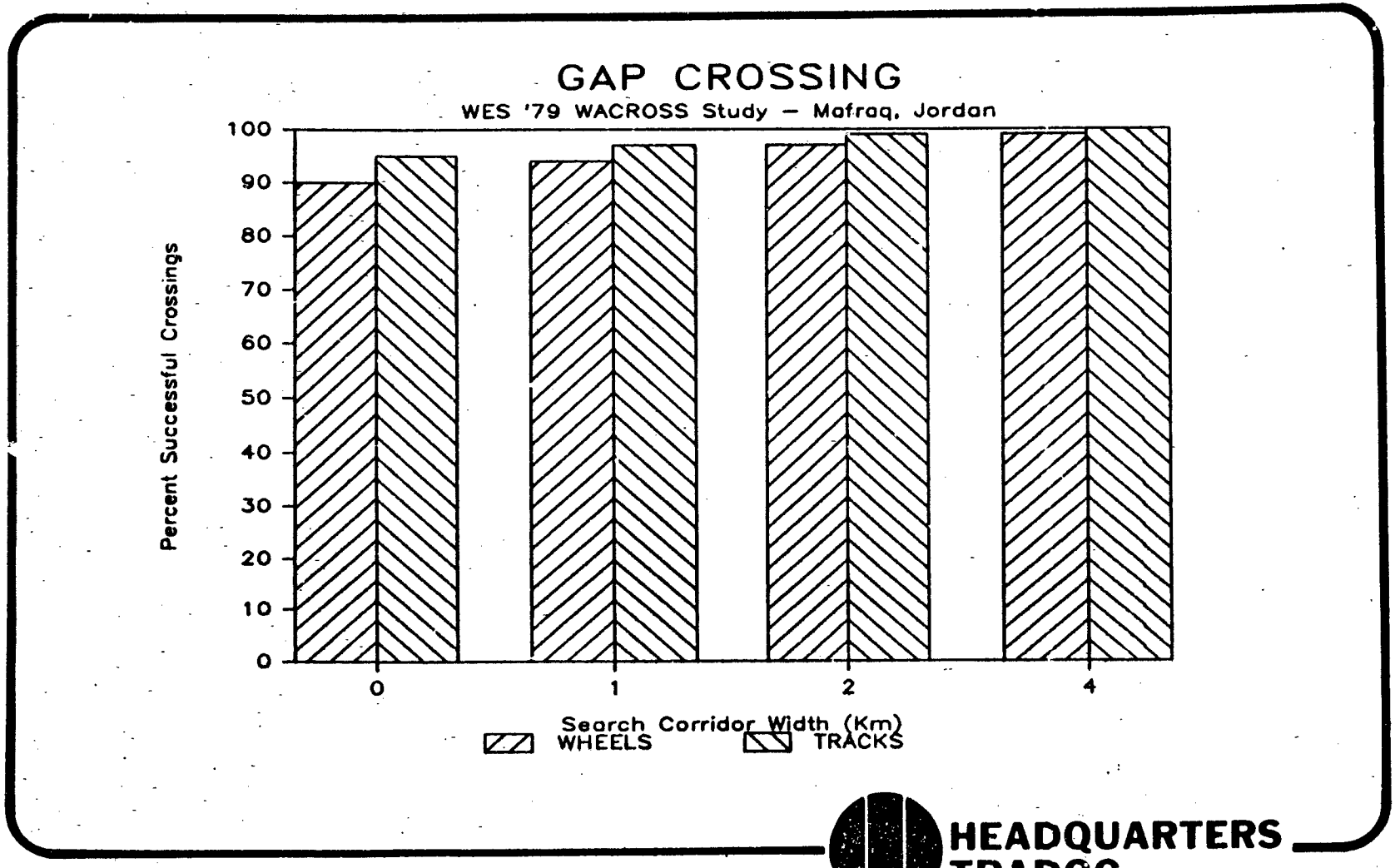
	DENIAL FACTOR			
	BOTTOM CROSSING	BANK CLEARANCE	EGRESS TRACTION	COMBINATION OF ONE OR MORE
WHEELED	8 %	80 %	97 %	99 %
TRACKED	2 %	55 %	48 %	60 %

HEADQUARTERS TRADOC

BACKUP SLIDE 16 - GAP CROSSING - MAFRAQ, JORDAN - 1979 WACROSS STUDY

The WACROSS study also evaluated the arid terrain of Mafraq, Jordan, and the results are depicted here. As with Lauterbach, on average, gaps are encountered every three to five kilometers in the Mafraq area. In this environment, wheeled and tracked vehicles are roughly comparable in their gap crossing capabilities. The tracked vehicles retained a small advantage but it is not significant.

The major factor that causes the difference between the Lauterbach and Mafraq environments is the soil characteristics found in the two areas. Wheeled vehicles can have considerable freedom of movement in the arid environments of the Middle East while in the temperate areas of the world, wheeled vehicles are not competitive with tracked vehicles in cross-country gap crossing situations. This is a critical distinction when procuring a military vehicle fleet with a world-wide commitment.

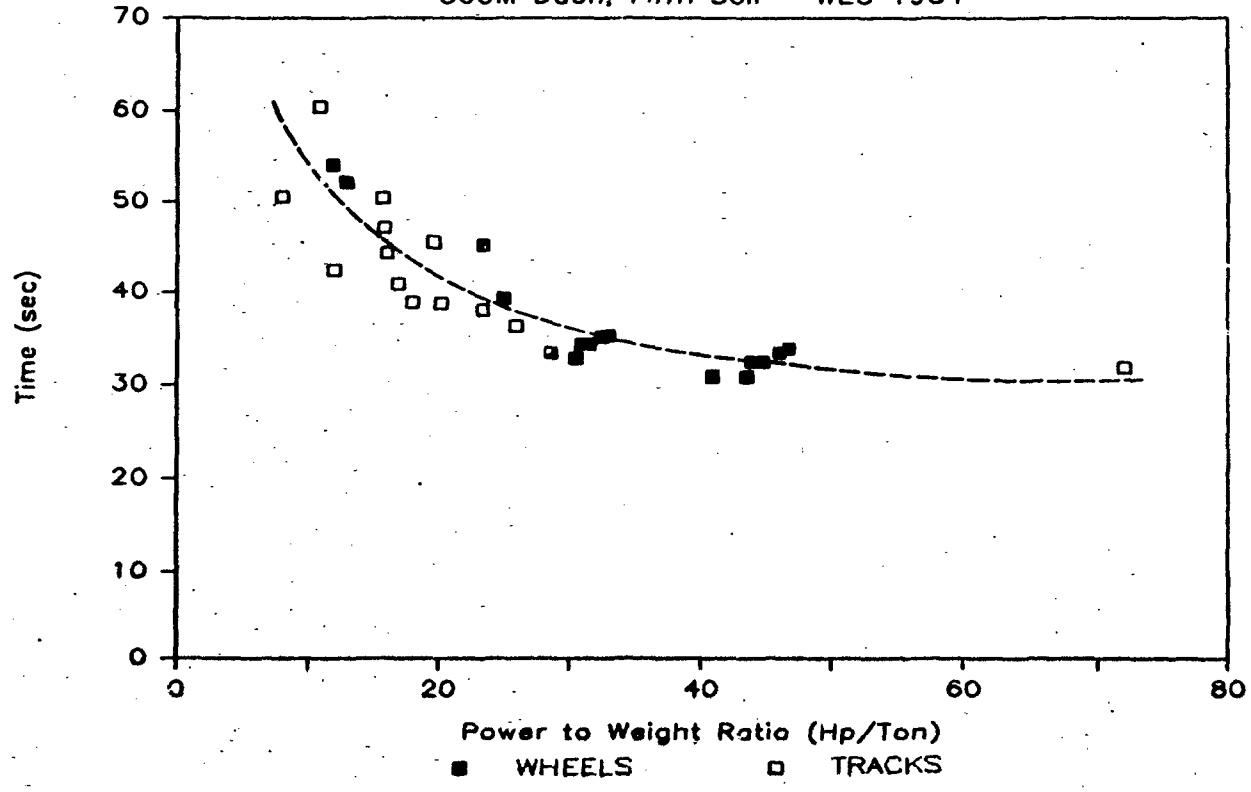

GAP CROSSING
WES '79 WACROSS Study – Mafraq, Jordan
Percent Successful Crossings
100
90
80
70
60
50
40
30
20
10
0
0
1
2
4
Search Corridor Width (Km)
WHEELS
TRACKS
HEADQUARTERS
TRADOC

BACKUP SLIDE 17 - VEHICLE ACCELERATION - 500 METER DASH

WES performed a computer simulation of acceleration times and found that on firm soil the primary determinant of acceleration time is power to weight ratio rather than a wheeled or tracked automotive configuration. The bias in favor of wheeled vehicles that one normally observes is a consequence of the fact that wheeled vehicles usually carry higher power to weight ratios than tracked vehicles. If wheeled and tracked vehicles were designed with similar power to weight ratios and transmission gearing, one would expect comparable acceleration times. WES validated this concept by modifing a M113 from the standard power to weight ratio of 12 hp/ton to 72 hp/ton. The computer model accurately predicted the measured performance of this modified vehicle. It is represented by the right most plot point on the graph.

VEHICLE ACCELERATION

500M Dash, Firm Soil – WES 1984

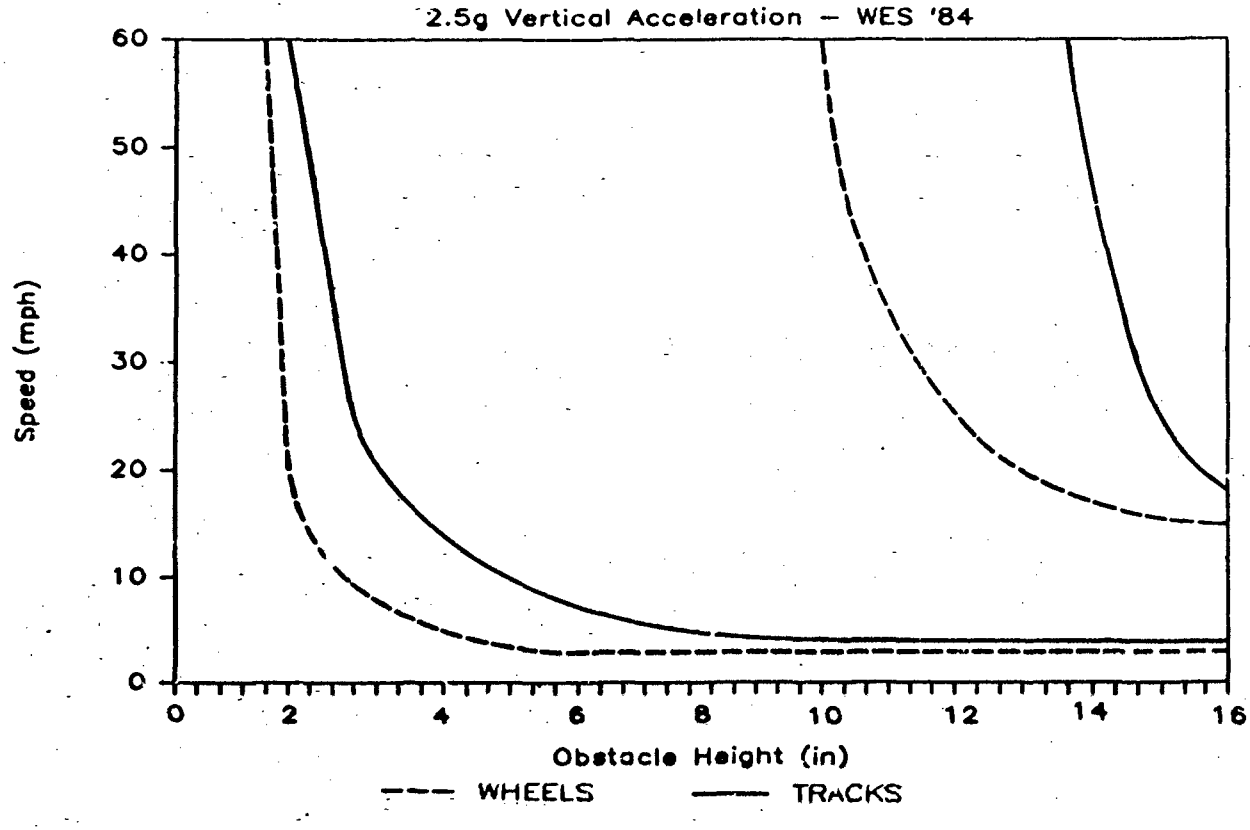


HEADQUARTERS
TRADOC

BACKUP SLIDE 18 - SHOCK & VIBRATION - 2.5 G VERTICAL ACCELERATION

Depicted here are plots of the upper and lower bounds of wheeled and tracked vehicle performance in the speeds that operators will maintain when encountering various size obstacles that impart a 2.5 g impact load into the vehicle. These data were developed by WES from the various mobility assessments that they have performed. WES believes that even though the upper and lower bounds for tracked vehicles are shifted to the right of wheeled vehicles, the magnitude of the shift is not significant and the two configurations are essentially comparable in their ability to handle terrain induced shock loads.

SHOCK AND VIBRATION



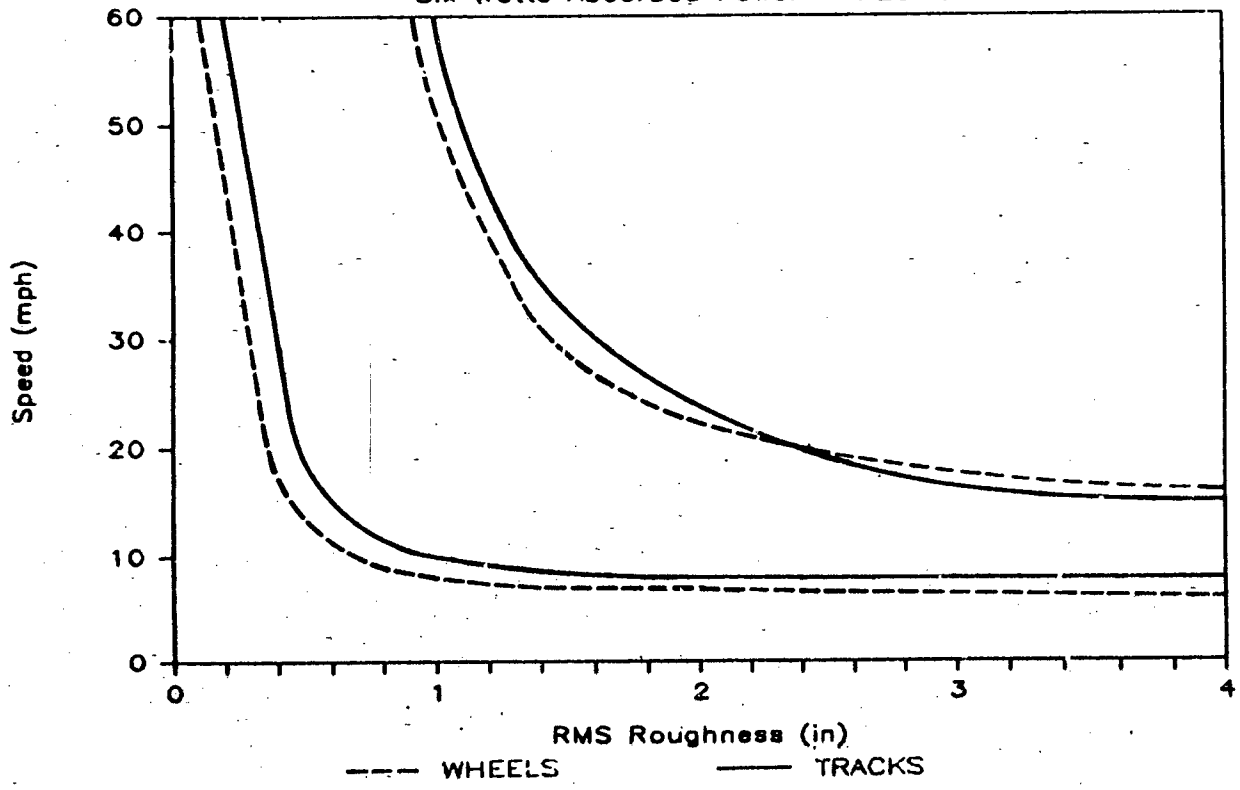
HEADQUARTERS
TRADOC

BACKUP SLIDE 19 - SHOCK & VIBRATION - 6 WATTS ABSORBED POWER

WES performed the sane analysis for absorbed power at the driver's seat and again found an insignificant difference in the observed performance of wheeled and tracked vehicles. Six watts is the level of continuous power absorption that human operators will voluntary subject themselves to for extended periods of time.

SHOCK AND VIBRATION

Six Watts Absorbed Power – WES '84



HEADQUARTERS
TRADOC

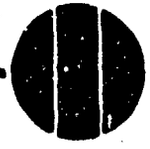
BACKUP SLIDE 20 - 1984 WES MOBILITY ANALYSIS - WHEELED VEHICLES

Depicted here are the set of eight high-mobility wheeled vehicles WES used in computing the Mean Percent Terrain Mobility and the Mission Performance Times presented on slides #27 and #28 of the main briefing. This is the same group of wheeled vehicles used in the soft-sand analysis depicted on backup slide #12. The corresponding group of tracked vehicles are depicted on backup slide #21.

1984 WES MOBILITY STUDY

WHEELED VEHICLES

NOMENCLATURE	GVW (TONS)	VCI
XM800 ARSV (6X6)	9.8	18
BTR 60 (8X8)	11.4	22
LAV-25 (8X8)	13.8	31
MC3 (PAPER - 4X4)	13.4	29
MFWS2 (PAPER - 4X4)	13.8	24
MC7 (PAPER - 6X6)	14.0	22
MC11 (PAPER - 8X8)	15.1	20
ACVT5 (PAPER - 6X6)	16.0	30
AVERAGE	13.4	24.5



HEADQUARTERS
TRADOC

BACKUP SLIDE 21 - 1984 WES MOBILITY ANALYSIS - TRACKED VEHICLES

Depicted here are the set of nine tracked vehicles that WES used in computing the Mean Percent Terrain Mobility and the Mission Performance Times presented in the main briefing.

1984 WES MOBILITY STUDY

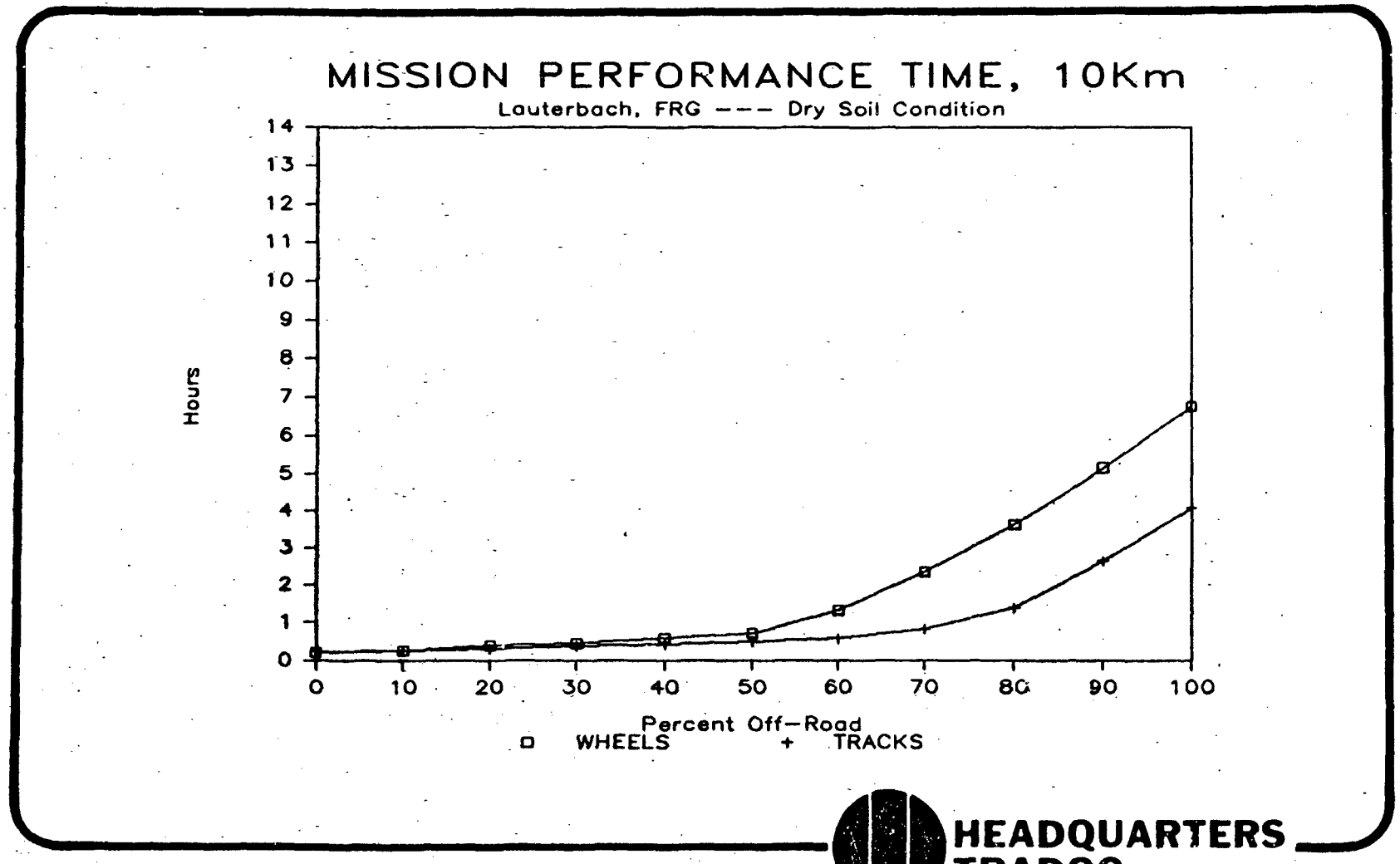
TRACKED VEHICLES

NOMENCLATURE	GVW (TONS)	VCI
XM88Ø ARSV	1Ø.Ø	12
M113A1	12.3	17
M2 BFV	23.5	13
M993 MLRS	27.2	15
T72	45.2	22
M6ØA3	55.Ø	2Ø
M1	57.5	23
MPWS4 (PAPER)	14.5	17
ACVT3 (PAPER)	16.Ø	17
AVERAGE	29.Ø	17.3

HEADQUARTERS
TRADOC

BACKUP SLIDE 22 - MISSION PERFORMANCE TIME - LAUTERBACH, FRG - DRY

Depicted here are the results from the WES analysis of mission performance times for Lauterbach, FRG, during the dry season. The analysis revealed that wheeled and tracked vehicles are very competitive in the amount of time that it takes to perform a 10km mission as long as the mission requires less than 50 percent off-road travel. Above the 50 percent level, the inherently superior cross-country mobility of tracked vehicles gives them an advantage that becomes more pronounced as less of the road network is employed.

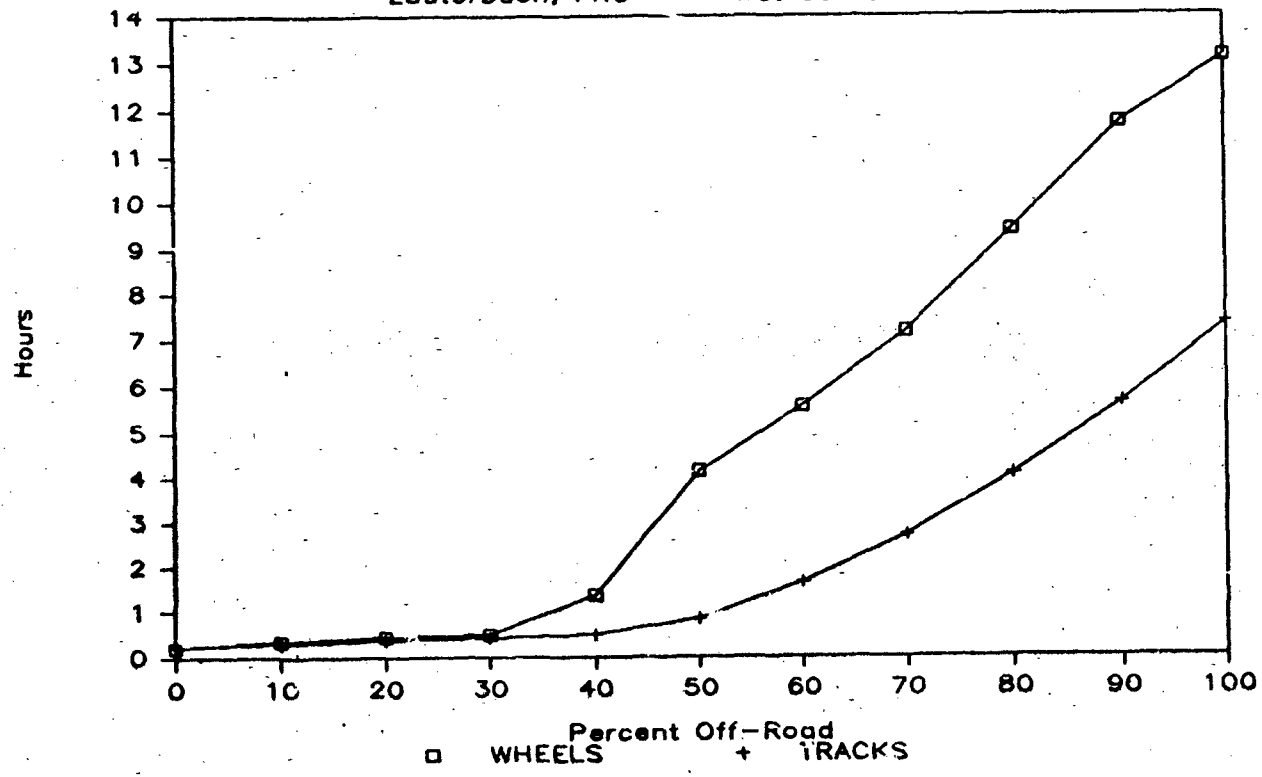

MISSION PERFORMANCE TIME, 10Km
Lauterbach, FRG --- Dry Soil Condition
Hours
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
Percent Off-Road
WHEELS
TRACKS
HEADQUARTERS
TRADOC

BACKUP SLIDE 23 - MISSION PERFORMANCE TIME - LAUTERBACH, FRG - WET

The WES analysis also looked at Lauterbach in the wet season and the results of that analysis are depicted here. The results are comparable to those from evaluating the terrain in the dry season except that the point where the two vehicle configurations begin to diverge is reduced to 30 percent off-road. The magnitude of the divergence is very significant. If we look at the 60 percent off-road level required by the tactical high mobility mission profile, we see approximately a four hour increase in the amount of time that a wheeled vehicle would require to perform a 10km mission. This time penalty is very significant from an operational utility perspective.

MISSION PERFORMANCE TIME, 10Km

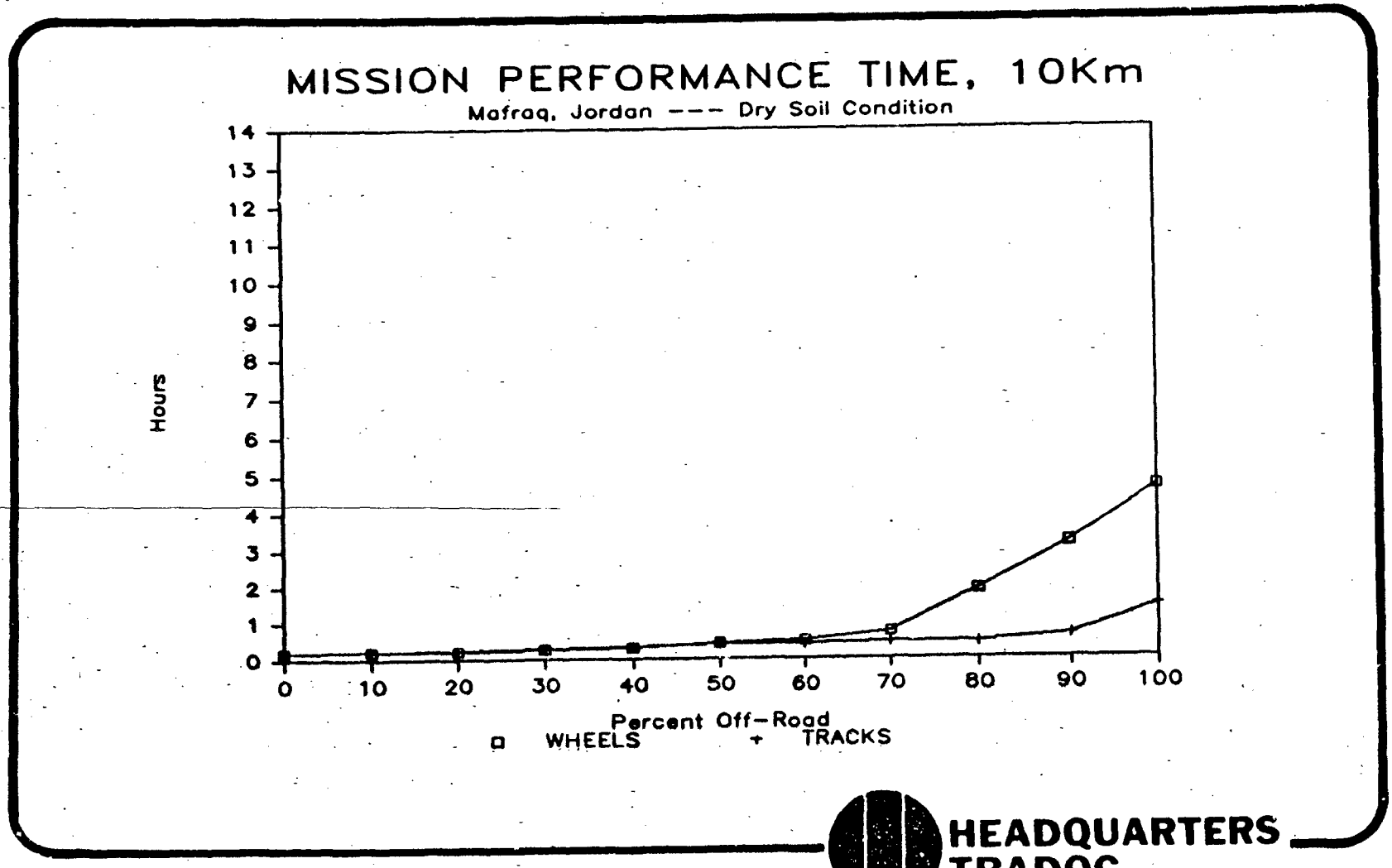
Lauterbach, FRG --- Wet Soil Condition



HEADQUARTERS
TRADOC

BACKUP SLIDE 24 - MISSION PERFORMANCE TIME - MAFRAQ, JORDAN - DRY

WES repeated the Mission Performance Times analysis in the arid Mafraq, Jordan, environment. The general pattern of wheeled and tracked vehicle mission performance times remained similar to the results from the Lauterbach analysis, except that the point where the wheeled vehicles became noncompetitive was shifted to the right of the graph. In the Mafraq dry season, wheeled vehicles remain competitive with tracked vehicles in missions requiring up to 70 percent off-road travel.

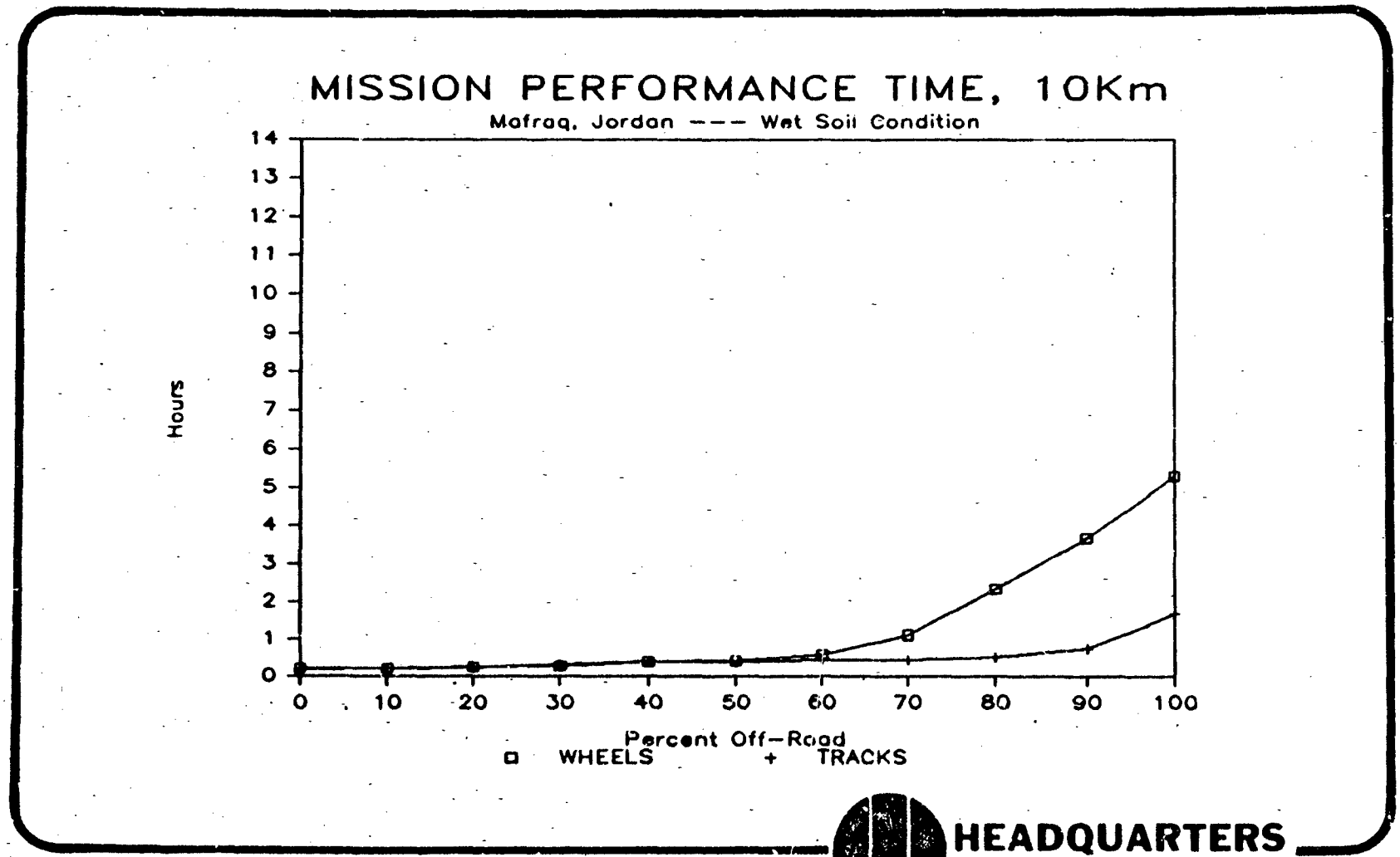


HEADQUARTERS
TRADOC

BACKUP SLIDE 25 - MISSION PERFORMANCE TIME - MAFRAQ, JORDAN - WET

In the Mafraq wet season, the performance degradation suffered by wheeled vehicles is relatively minor. Wheeled and tracked vehicles are competitive in mission performance times in missions requiring up to 60 percent off-road travel.

Given the 60 percent off-road mobility requirement of tactical high mobility vehicles, we see that wheeled vehicles meet this criterion in the arid Mafraq, Jordan environment.

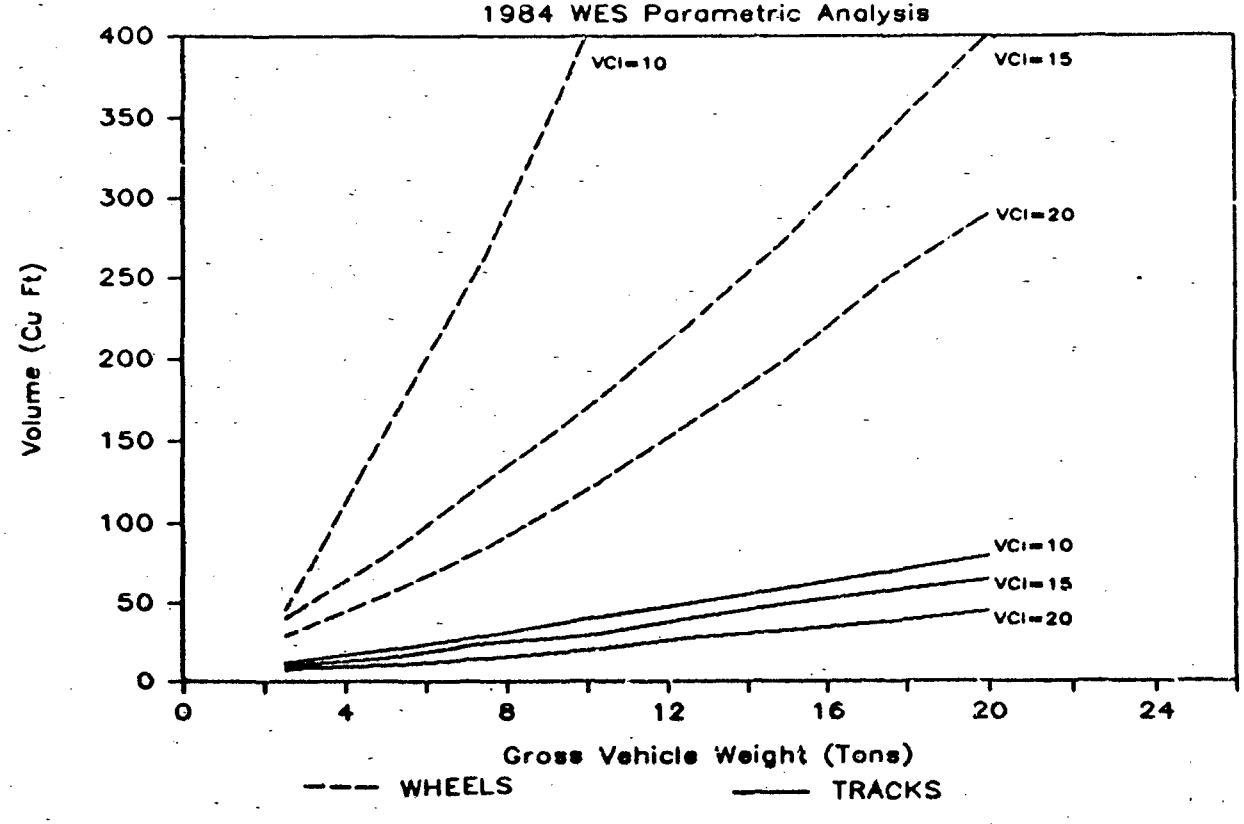

MISSION PERFORMANCE TIME, 10Km
Mafraq, Jordan --- Wet Soil Condition
Hours
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
Percent Off-Road
WHEELS
TRACKS
HEADQUARTERS
TRADOC

BACKUP SLIDE 26 - VEHICLE SUSPENSION VOLUME - 1984 WES PARAMETRIC ANALYSIS

Depicted here are the results of WES's parametric analysis of the volume that would be dedicated to suspension components in wheeled and tracked vehicles in the 2.5 to 20 ton gross vehicle weight class. The analysis was repeated for various target values of VCI from 10 to 20. The vertical axis of the graph is cubic feet of suspension components and the horizontal axis is gross vehicle weight in tons. By inspection, wheeled vehicles require considerably more vehicle volume to achieve the same VCI level as tracks. This difference is on the order of six times greater for a wheeled vehicle with a VCI of 20 in the 10 to 20 ton GVW class.

VEHICLE SUSPENSION VOLUME

1984 WES Parametric Analysis



HEADQUARTERS
TRADOC

BACKUP SLIDE 27 - ARMORED VEHICLE SUSPENSION VOLUME - 1985 WES PARAMETRIC ANALYSIS

WES expanded their parametric analysis of suspension components to look at the impact on overall vehicle size if we were to attempt to achieve a VCI of 20 in a wheeled and tracked vehicle with an a fixed interior volume. The results of that analysis are depicted here. The cargo volume (230 cubic feet) of a M113 was selected as the fixed useable volume. The automotive machinery space (engine, transmission & cooling) was allowed to vary to accommodate the larger engine that would be required for the higher gross vehicle weights. The difference between the suspension volume requirements of the wheeled and tracked configurations is quite significant.

1985 WES PARAMETRIC ANALYSIS
ARMORED VEHICLE SUSPENSION VOLUME COMPARISON
$VCI_1 = 20$

GROSS VEHICLE WEIGHT	CARGO AREA	AUTOMOTIVE MACHINERY	SUSPENSION	
			WHEELED	TRACKED
10 TONS	230 FT^3	378 FT^3	125 FT^3	22 FT^3
15 TONS	230 FT^3	393 FT^3	220 FT^3	32 FT^3
20 TONS	230 FT^3	500 FT^3	315 FT^3	100 FT^3

HEADQUARTERS
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1985 WES PARAMETRIC ANALYSIS
ARMORED VEHICLE SUSPENSION VOLUME COMPARISON
$VCI_1 = 20$

GROSS VEHICLE WEIGHT	TOTAL VEHICLE VOLUME TRACKED	WHEELED	DIFFERENCE
10 TONS	630 FT^3	733 FT^3	+ 16 %
15 TONS	655 FT^3	843 FT^3	+ 29 %
20 TONS	830 FT^3	1045 FT^3	+ 28 %

HEADQUARTERS
TRADOC

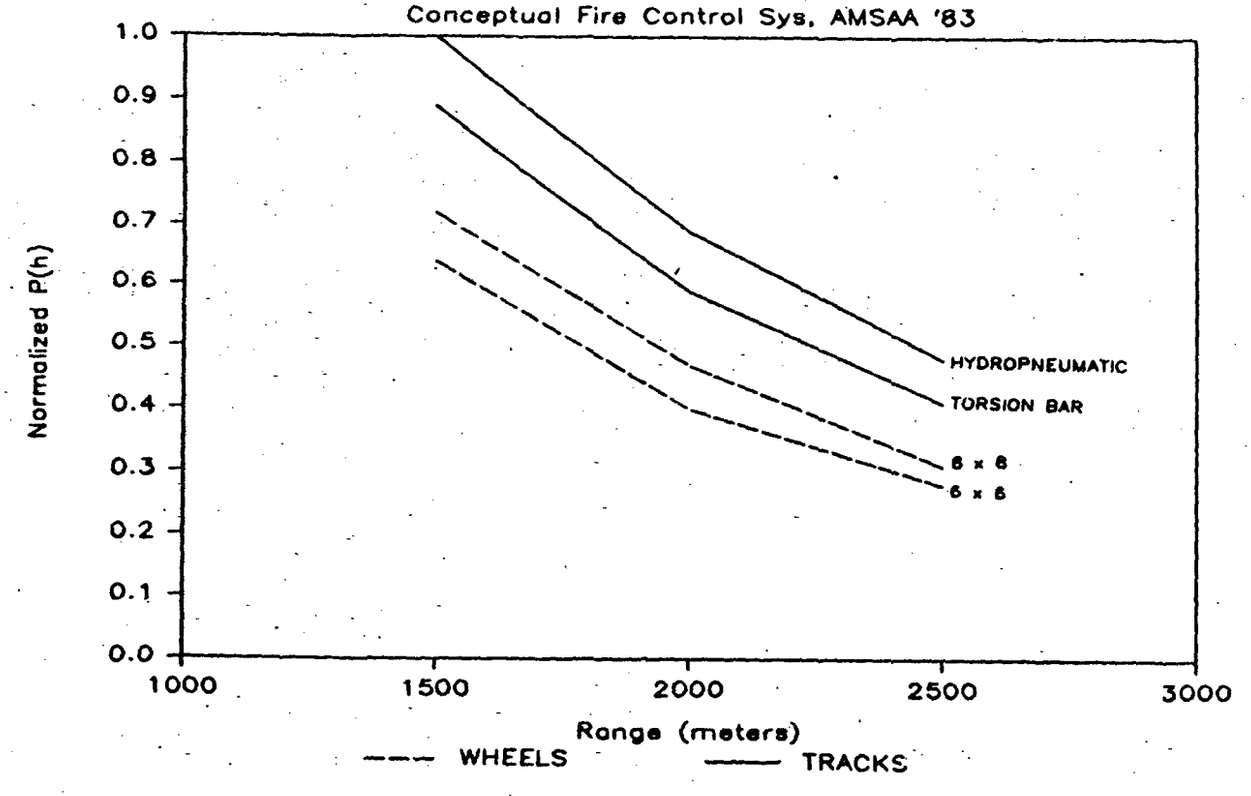
BACKUP SLIDE 29 - GUN PLATFORM STABILITY

In 1983, AMSAA performed an analysis of conceptual fire control systems for lightweight armored vehicles to identify the differences in probability of hit, P(h), that would occur with various fire control systems on wheeled and tracked platforms. The best results were obtained for a fire control system consisting of a two axis stabilized gun director (azimuth and elevation), with automatic target tracking and an inertially stabilized rate aiding device to compensate for the relative motion of the shooting vehicle with the target. The graph depicts the normalized performance of this fire control system on the two tracked and two wheeled platforms that were evaluated in the analysis. The results for the other less capable fire control systems followed the same pattern with respect to the chassis performance with the P(h) values being lower. The hydropneumatic suspended tracked vehicle offers the most stable gun platform. It is followed by the high strength torsion bar suspended tracked vehicle, the 8X8 independently suspended wheeled vehicle and the 6X6 independently suspended wheeled vehicle. The performance differences between the various chassis configurations were consistent as the engagement range was varied from 1500 to 2500 meters.

The primary contributor to this variation in performance between wheeled and tracked vehicles is the undamped tire bounce problem that occurs with wheeled vehicles. The tires act like springs as they encounter obstacles and undamped oscillations are introduced into the chassis of the vehicle that must be overcome by the stabilization system.

GUN PLATFORM STABILITY

Conceptual Fire Control Sys, AMSAA '83



HEADQUARTERS
TRADOC

BACKUP SLIDE 30 - LAV RELIABILITY TEST

Depicted here are the results from the 1982 reliability test for the Marine Corps' Light Armored Vehicle. The data are only for the vehicle chassis and do not include any mission equipment. As can be seen from inspection, the GM 8X8 was the best performer of the group. It enjoyed a considerable reliability advantage over the competitors. The performance of the Cadillac Gage vehicles was roughly comparable to the Alvis tracked vehicles.

This particular test did not prove much from a wheels versus tracks perspective. The Alvis tracked alternative and the Cadillac Gage wheeled alternatives all suffered a high amount of down time that was independent of their automotive configuration.

LAV RELIABILITY TEST
1982
AUTOMOTIVE COMPONENTS ONLY

	MMBF	MTTR (HRS)	MR
WHEELED			
GM - 8 X 8	1405	1.7	.65
CG - 4 X 4	363	1.9	.56
CG - 6 X 6	153	3.5	2.72
TRACKED			
ALVIS	151	2.5	2.60

HEADQUARTERS
TRADOC

BACKUP SLIDE 31 - THIN-SKINNED VEHICLE HARDWARE COSTS

We performed this excursion looking at the hardware procurement costs for thin-skinned wheeled and tracked vehicles. These five vehicles are not directly comparable since the tracked vehicles offer higher levels of operational mobility. If wheeled and tracked vehicles offering comparable levels of off-road mobility were compared, the magnitude of the difference would probably be reduced. Given this qualification, we see that on average wheeled vehicles are 50 to 66 percent lower in procurement cost on a cost per pound of payload basis.

THIN-SKINNED VEHICLE HARDWARE COSTS

	PAYLOAD (LBS)	UNIT COST (FY-86)	COST/LB
WHEELED VEHICLES			
M998 (HMMWV)	2,500	$ 21,783	$ 8.71
MTT	7,600	59,356	7.81
M985 (HEMTT)	20,000	111,787	5.59
AVERAGE			$ 7.37
TRACKED VEHICLES			
SUSV	4,400	$ 114,696	$ 26.07
M548	12,000	162,820	13.57
AVERAGE			$ 19.82

HEADQUARTERS
TRADOC

BACKUP SLIDE 32 - LIGHT ARMORED VEHICLE HARDWARE COSTS

Depicted here are the hardware procurement costs for light armored vehicles. The data show a high degree of variability. These costs are driven much more by quantities of buy and manufacturer capabilities than they are by automotive configuration.

LIGHT ARMORED VEHICLE HARDWARE COST

	PAYLOAD (LBS)	UNIT COST (FY-86)	COST/LB
WHEELED VEHICLES			
LAV	5,500	$ 262,089	$ 47.65
TRACKED VEHICLES			
M113A2	4,000	$ 153,083	$ 38.27
M993 (CHASSIS)	24,000	456,989	19.04

HEADQUARTERS
TRADOC

BACKUP SLIDE 33 - PROCUREMENT COSTS - CADILLAC GAGE COMPANY

We contacted the Cadillac Gage Company and obtained projected procurement costs for their wheeled V-300A1 Commando and tracked Commando Stingray. Both vehicles are equipped with the same 105mm turret and are intended to support an Armored Gun System (AGS) type of mission profile. The wheeled vehicle is projected to be slightly lower in cost, but this is for a lighter vehicle with less ballistic protection than the tracked vehicle. If the vehicles were directly comparable in protection levels, the procurement costs would probably be within 10 percent of each other.

PROCUREMENT COST - 100 UNITS

	COST (FY-84)
O CADILLAC GAGE COMPANY	
OO STINGRAY COMMANDO	$ 1.2 M
- TRACKED - 105 MM MAIN GUN - 21 TONS GVW	
OO V-300A1 COMMANDO (DESIGN CONCEPT)	$ 1.0 M
- WHEELED 6X6 - 105 MM MAIN GUN - 16 TONS GVW	

HEADQUARTERS
TRADOC

BACKUP SLIDE 34 - OPERATING AND SUPPORT COSTS

Depicted here are the operating and support costs provided by the HQ TRADOC Dutch and Canadian liaison officers. Both reported that it has been their respective countries' experience that wheeled armored vehicles are cheaper to operate. The magnitude of their measured difference correlates well with the projection of a one-third reduction in wheeled armored vehicle life-cycle costs given to us by the French Liaison Officer and our own Mobile Protected Gun System (MPGS) analysis that projected a 32 percent reduction.

OPERATING AND SUPPORT COSTS

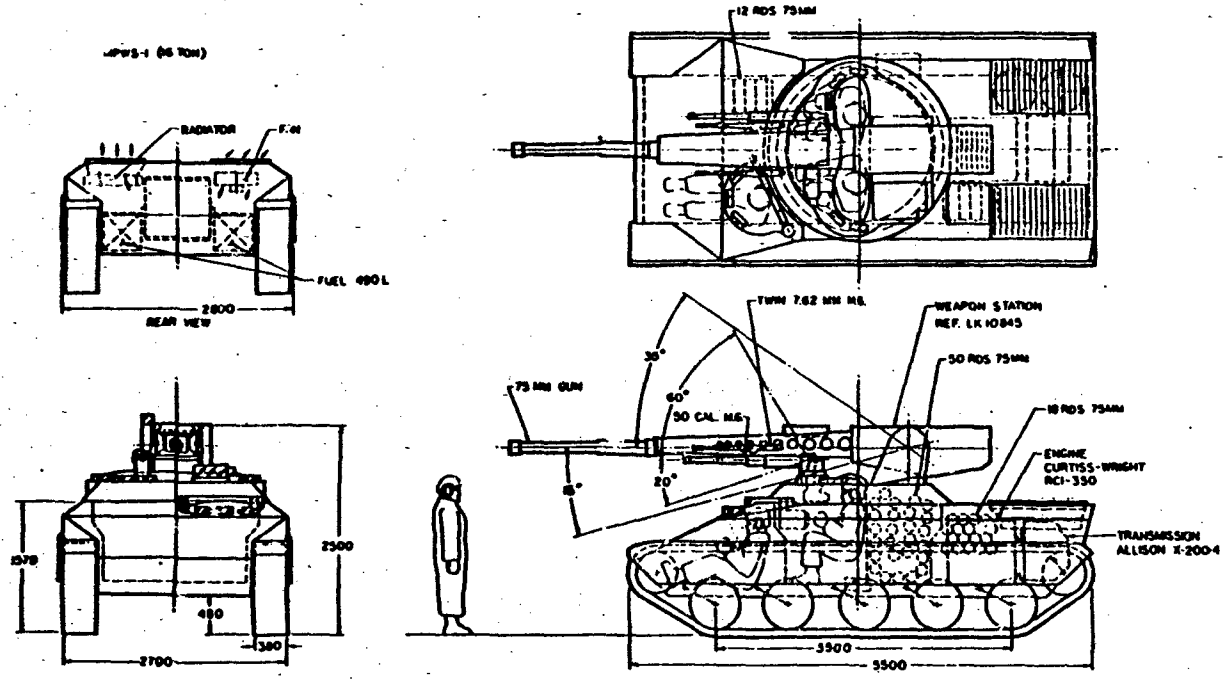
- NETHERLANDS -- MECHANIZED INFANTRY BATTALION -- 1982
  - DAF 408 -- WHEELED APC
    - 14.0 M GUILDERS PER YEAR O&S
  - YPR 765 -- TRACKED APC (DUTCH VERSION OF FMC 113)
    - 17.6 M GUILDERS PER YEAR O&S
- CANADA -- OPERATIONAL EXPERIENCE -- 1984
  - FMC M113A1 TRACKED APC
    - 11.16 CANADIAN DOLLARS PER MILE O&S
  - GM GRIZZLY WHEELED APC
    - 8.69 CANADIAN DOLLARS PER MILE O&S

HEADQUARTERS
TRADOC

BACKUP SLIDE 35 - ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM - CONCEPT 3

In the 1979 Armored Combat Vehicle Technology Program, directly comparable wheeled and tracked Mobile Protected Weapon System (MPWS) candidates were defined. Both vehicles had a combat loaded weight of 16 tons, were powered by the same 375 hp rotary engine, mounted the same 75mm external gun, and carried three man crews. Depicted here is concept three, the tracked candidate.

ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM (1979)
CONCEPT 3

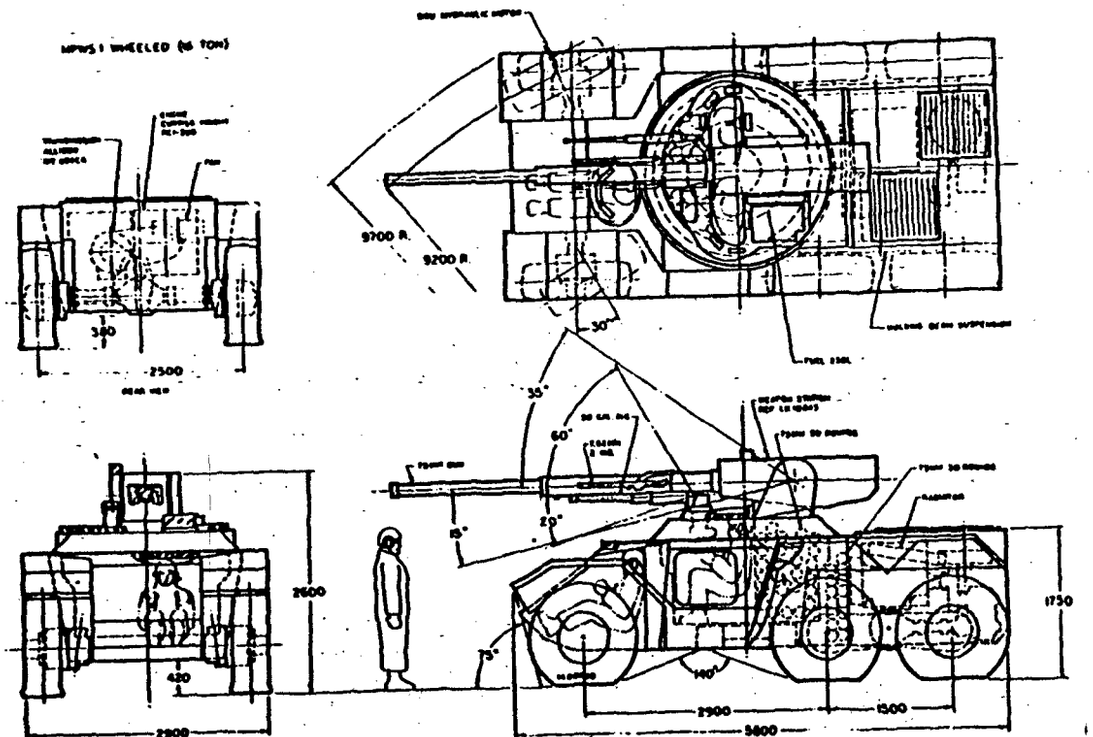


HEADQUARTERS
TRADOC

BACKUP SLIDE 36 - ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM - CONCEPT 5

Depicted here is concept five, the wheeled candidate.

ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM (1979)
CONCEPT 5



HEADQUARTERS
TRADOC

BACKUP SLIDE 37 - VOLUME COMPARISON OF BASE VEHICLES

If we perform a direct dimensional comparison of the two concept vehicles, we see that the wheeled alternative is larger in all dimensions and that this increase in size translates into an overall 13.6 percent increase in vehicle volume. Additionally, we see that the VCI values of the two vehicles favor the tracked alternative and the wheeled alternative requires a C-141B for air transport.

ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM (1979)
VOLUME COMPARISON OF BASE VEHICLES

	CONCEPT 3 TRACKED 16T 75MM 375HP	CONCEPT 5 WHEELED 16T 75MM 375HP	PERCENT DIFFERENCE
LENGTH	5.5 M	5.8 M	+ 5.5 %
WIDTH	2.8 M	2.9 M	+ 3.6 %
HEIGHT	2.5 M	2.6 M	+ 4.0 %
VOLUME	38.5 M^3	43.7 M^3	+ 13.6 %
VCI_1	17	30	
AIR TRANS	C-130	C-141B	

HEADQUARTERS TRADOC

BACKUP SLIDE 38 - PERCENT TERRAIN MOBILITY - BASE VEHICLES

If we look at the impact of the wheeled vehicle's higher VCI level on overall terrain mobility, we see that it suffers a mobility disadvantage, particularly in the temperate wet and the artificial sand conditions.

ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM (1979)
PERCENT TERRAIN MOBILITY

	CONCEPT 3 TRACKED 16T 75MM 375HP	CONCEPT 5 WHEELED 16T 75MM 375 HP	DIFFERENCE
LAUTERBACH, FRG			
DRY (8 MO)	96.7 %	90.1 %	- 6.6 %
WET (2 MO)	91.8 %	77.4 %	- 14.4 %
SNOW (2 MO)	85.6 %	79.3 %	- 6.3 %
MAFRAQ, JORDAN			
DRY (11 MO)	99.6 %	91.7 %	- 7.9 %
WET (1 MO)	99.4 %	90.9 %	- 8.5 %
SAND (ARTIFICIAL)	98.7 %	78.1 %	- 20.6 %

HEADQUARTERS
TRADOC

BACKUP SLIDE 39 - HARDWARE COSTS - BASE VEHICLES

If we look at the hardware procurement cost projections for the two vehicles, we see that they are roughly comparable in cost. The primary area of divergence between the two vehicle configurations is in suspension costs. The suspension costs of the wheeled vehicle are projected to be twice the level of the tracked alternative. The costs presented are in FY-81 dollars for a projected buy quantity of 3000 vehicles.

ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM (1979)
HARDWARE COSTS

COMPONENT	CONCEPT 3 TRACKED 16T 75MM 375 HP	CONCEPT 5 WHEELED 16T 75MM 375 HP	DIFFERENCE
HULL	$ 49.2 K	$ 52.6 K	$ + 3.4 K
SUSPENSION	27.0	53.9	+ 26.9
POWER PACKAGE	63.7	63.6	- 0.1
AUXILIARY AUTOMOTIVE	8.1	9.1	+ 1.0
TURRET	44.6	44.6	
PRIMARY ARMAMENT	64.0	64.0	
SPECIAL EQUIPMENT	4.6	5.1	+ 0.5
INTEGRATION AND ASSEMBLY	8.9	10.0	+ 1.1
ANCILLARY EQUIPMENT	27.0	27.0	
TOTAL	$ 297.1 K	$ 329.9 K	$ + 32.8 K

HEADQUARTERS
TRADOC

BACKUP SLIDE 40 - VOLUME COMPARISON - COMPARABLE VCI

If we equip the wheeled alternative with larger tires, to bring its VCI level in line with the tracked alternative, we see that the vehicle grows considerably in size and that it will now require a C-5A for air transport.

This vehicle comparison provides a good depiction of the wheels versus tracks issue when vehicles are designed to perform identical mission roles. In order to keep the size of the wheeled vehicle within bounds, the designers chose to accept a higher VCI level with a corresponding decrease in cross-country mobility. Even with this trade-off, the wheeled alternative still required a C-141B for air transport. When the wheeled alternatives tires are increased to the size necessary to give it a VCI comparable to the tracked alternative, the wheeled vehicle is no longer air transportable by a C-141B.

The cost comparison of the two vehicle configurations shows that the costs are comparable for most components. The only exception is the suspension system of the wheeled vehicle is projected to cost almost twice that of the tracked vehicle. The contribution of the suspension cost to overall vehicle cost is not great and the projected procurement costs are within 10 percent of each other.

Additionally, one would expect the wheeled alternative to be an inferior gun platform. However, one would expect it to offer a lower acoustic signature, lower operating and support costs and an intra-theater self-deployment capability.

ARMORED COMBAT VEHICLE TECHNOLOGY PROGRAM (1979)
COMPARABLE VCI_1

	CONCEPT 3 TRACKED 16T 75MM 375HP	CONCEPT 5 WHEELED 16T 75MM 475HP	PERCENT DIFFERENCE
LENGTH	5.5 M	5.8 M	+ 5.5 %
WIDTH	2.8 M	3.2 M	+ 15.1 %
HEIGHT	2.5 M	2.9 M	+ 17.7 %
VOLUME	38.5 M^3	54.9 M^3	+ 42.6 %
VCI_1	17	17	
AIR TRANS	C-130	C-5A	

HEADQUARTERS
TRADOC

BACKUP SLIDE 41 - COUNTRIES PRODUCING LIGHT ARMORED VEHICLES - WHEELED

We surveyed the 1983-1984 edition of Jane's Armour and Artillery and identified this list of countries that were producing wheeled armored vehicles. The numbers in parentheses correspond to the number of manufacturers within each country. Communist countries were assumed to have only one manufacturer since all production facilities are owned and operated by the government.

COUNTRIES PRODUCING LIGHT ARMORED VEHICLES
WHEELED VEHICLES

AUSTRIA (1)
BELGIUM (1)
BRAZIL (1)
CANADA (1)
CHILE (2)
CZECHOSLOVAKIA (1)
EGYPT (1)
FRANCE (3)
FRG (3)
IRELAND (2)
ISRAEL (2)
ITALY (4)
JAPAN (1)
KOREA (SOUTH) (1)
PORTUGAL (1)
ROMANIA (1)
SOUTH AFRICA (1)
SOVIET UNION (1)
SPAIN (1)
SWITZERLAND (1)
UNITED KINGDOM (5)
UNITED STATES (3)
YUGOSLAVIA (1)
ZIMBABWE (1)

24 COUNTRIES
40 MANUFACTURERS

HEADQUARTERS
TRADOC

BACKUP SLIDE 42 - COUNTRIES PRODUCING LIGHT APMORED VEHICLES - TRACKED

This is the list of countries currently producing light tracked vehicles.

The reason for many more manufacturers producing wheeled armored vehicles is that it is easier to get into the wheeled armored vehicle business. Primitive wheeled armored vehicles are little more than an armored hull sitting on a truck chassis. The investment in plant and machinery necessary to build this type of vehicle is minimal. State of the art high mobility wheeled armored vehicles require considerably more plant and equipment investment.

This concludes the backup slide portion of the Wheeled Versus Tracked Vehicle Study briefing.

COUNTRIES PRODUCING LIGHT ARMORED VEHICLES
TRACKED VEHICLES

ARGENTINA (1)
AUSTRIA (1)
BELGIUM (2)
CHINA (1)
FRANCE (3)
FRG (2)
GREECE (1)
ITALY (1)
JAPAN (1)
SOVIET UNION (1)
SWEDEN (2)
SWITZERLAND (1)
TAIWAN (1)
UNITED KINGDOM (2)
UNITED STATES (2)
YUGOSLAVIA (1)

16 COUNTRIES
23 MANUFACTURERS

HEADQUARTERS
TRADOC

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Appendix A

Tasking Message

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ATTG:	2	ATTF:	/	ATMD:		INS:		ACC:		RT:
ATLU:	2	ATAM:		ATCH:		NSW:		PMO:		SP: CH
ATDO:	2	ATCS:		ATPA:		TCF:		TCC:		XR: CH
ATRO:		ATCM:		ATJA:		FMR:		SSD:		NC: 2
ATRM:		ATCE:		ATFE:		DAR:		MP[redacted]:		QC:
ATPL:		ATIG:		EOC:		SAC:			1	
ATEN:										

RTTUZYUW RUFAOWD3417 1370626-UUUU--RUCLAIA.

ZNR UUUUU

R 151924Z MAY 84

FM DA WASHDC //DAMO-FD//

TO RUCLAIA/CDR TRADOC FT MONROE VA//ATCD-A//

RUKLDAR/CDRDARCOM ALEX VA //DRCDE//

INFO RUWTFHA/CDRUSACAC FT LEAVENWORTH KS //ATZL-CAM-I//

RUEOAGE/CDR LOGC FT LEE VA//ATCL-R//

RUWJHRA/CDRUSAICS FT HUACHUCA AZ //ATSI-CD//

RUCLDIA/CDRSIGCEN FT GORDON GA //ATZH-CD//

BT

UNCLAS

SUBJECT: WHEELED VS. TRACKED VEHICLES STUDY

1. OVER THE PAST SIX MONTHS NUMEROUS QUESTIONS HAVE BEEN RAISED ON THE PROS AND CONS OF TRACKED AND WHEELED VEHICLES GIVEN CERTAIN ENVIRONMENTAL CONDITIONS. A WATERWAYS EXPERIMENTATION STATION (WES) STUDY, CONDUCTED BY THE CORPS OF ENGINEERS, EXAMINED WHEELED AND TRACKED VEHICLE CAPABILITIES OVER VARIED TYPES OF TERRAIN IN WEST GERMANY IN BOTH WET AND DRY SEASONS; HOWEVER, IT DID NOT ADDRESS ANY OPERATIONAL FACTORS OTHER THAN MOBILITY.

2. THE ARMY NEEDS A QUANTIFIABLE AND DEFENDABLE FOUNDATION UPON WHICH TO BASE ITS FUTURE VEHICULAR SELECTIONS BETWEEN THE TRACKED

AND WHEELED VEHICLE CATEGORIES. THEREFORE, REQUEST HQ, TRADOC PROVIDE A WRITTEN REPORT AND BRIEFING TO THIS HQS NLT 31 JUL 84 DETAILING THE CAPABILITIES AND LIMITATIONS OF WHEELED AND TRACKED VEHICLES WHICH THE ARMY CAN USE AS EVALUATION CRITERIA FOR DETERMINING WHICH CATEGORY OF VEHICLE IS PREFERABLE FOR EACH MISSION AREA AND FUNCTIONAL APPLICATION. FOR CBT, CS AND CSS MISSION AREAS THE RELATIVE IMPORTANCE OF TERRAIN CONSIDERATIONS IN COMPARISON TO OTHER FACTORS, SHOULD BE SPECIFIED. ALL APPROPRIATE TERRAIN TYPES SHOULD BE CONSIDERED.

3. THE FOLLOWING QUESTIONS SHOULD BE CONSIDERED IN CONNECTION WITH THIS STUDY:

A. WHAT ARE THE ADVANTAGES AND DISADVANTAGES OF WHEELED VEHICLES? TRACKED VEHICLES? AREAS OF CONSIDERATION SHOULD INCLUDE: MOBILITY, MAINTENANCE MMTS, LIFE CYCLE COSTS, UNIT PRODUCTION COSTS, ROTE COSTS, TRANSPORTABILITY, SURVIVABILITY, PAYLOAD CAPACITY, ETC.

B. IS THE ARMY FULLY EXPLOITING THE ADVANTAGES OF WHEELED VEHICLES?

C. ARE THERE ANY MISSIONS WHICH OUGHT TO BE EXCLUSIVELY ACCOMPLISHED BY WHEELED VEHICLES OR EXCLUSIVELY BY TRACKED VEHICLES? FOR EXAMPLE, MISSIONS SUCH AS LOGISTICS SUPPORT, COMMAND AND

CONTROL, IEW, COMMUNICATIONS, ETC, MIGHT NOT NEED TO HAVE VEHICLES WHICH CAN HABITUALLY TRAVERSE SOFT SOIL AND RUGGED TERRAIN? THEREFORE, THESE MISSIONS MIGHT BE PERFORMED BETTER BY USING WHEELED VEHICLES.

D. IN PEACETIME COULD WHEELED VEHICLES BE SUBSTITUTED FOR TRACKED VEHICLES TO SAVE MAINTENANCE AND OTHER COSTS?

E. DO WE NEED TO PROVIDE SOME SHORT DISTANCE MOBILITY ENHANCEMENT CAPABILITY FOR WHEELED VEHICLES IN WARTIME?

F. DOES THE HALF-TRACK VEHICLE CONCEPT HAVE SUFFICIENT MERIT TO WARRANT NOTE?

G. COMPARE WHEELED VS. TRACK VEHICLE SHOCK AND VIBRATION. DOES EITHER CATEGORY CAUSE SIGNIFICANTLY GREATER DETRIMENTAL EFFECTS TO SPECIAL MISSION EQUIPMENT: E.G. IFW EQUIPMENT, ETC?

H. DOES EITHER CATEGORY OF VEHICLE HAVE AN ADVANTAGE IN PROVIDING ONBOARD POWER GENERATION?

I. IS THE DEGRADATION IN MOBILITY CAUSED BY TOWING TRAILERS GREATER FOR EITHER CATEGORY OF VEHICLE? THIS SHOULD BE CROSS-REFERENCED TO THE POWER GENERATION QUESTION ABOVE: I.E. IF EITHER CATEGORY OF VEHICLES CANNOT HABITUALLY GENERATE ONBOARD POWER, THE MOBILITY OF THE RELATED SYSTEM MUST BE ASSESSED ON A BASIS WHICH

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INCLUDES THE TOWING OF ANY APPROPRIATE GENERATOR TRAILERS.

4. POC THIS HEADQUARTERS IS LTC PETE DALTON, AV 225-7416.

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Appendix B

Study Plan

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DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23651

REPLY TO
ATTENTION OF: ATCD-AC

31 August 1984

SUBJECT: Combat Developments Study Plan: Wheeled vs Tracked Vehicle Study

HQDA (DAMO-FD)
WASH DC 20310

1. References:

a. Message, HQDA, DAMO-FD, 151924Z May 84, Subject: Wheeled vs Tracked Vehicle Study.

b. Letter, HQ TRADOC, ATCD-AC, 17 Aug 84, SAB.

2. In reference a, HQ TRADOC was tasked by ODCSOPS (DAMO-FD) to conduct an analysis of the factors used in developing wheeled and tracked vehicle operational requirements and to lay the foundation for the development of specific criteria upon which to base future decisions regarding wheeled and tracked vehicles.

3. In reference b, HQ TRADOC forwarded a preliminary study plan to HQDA (DAMO-FD) outlining a proposed methodology and establishing a time schedule for completing the study. Several minor changes were suggested for the study plan and they have been incorporated in the attached version.

4. Request approval of the attached Wheeled vs Tracked Vehicle Study Plan.

5. HQ TRADOC POC is Mr Kenneth L. Boyd, ATCD-AC, AV 680-3037, FTS 931-3037.

FOR THE COMMANDER:

S. D. SERAFINI
LTC, GS
Asst AG

1 Encl
as

CF:
HQDA
SAUS-OR (LTC Gardepe)/DAMO-FDT (LTC Dalton)
Cdr
HQ AMC (AMCCP-EV (Mr Dodds)/AMCDE-SS (Mr McGowan)/AMCDE-SG (Mr Duggan)/
AMCDI (Mr Howell))
USACAC (ATZL-CAM-S (LTC Kadel))
USALOGC (ATCL-MGM (Mr Russakoff))
(over)

ATCD-AC 31 August 1984
SUBJECT: Combat Developments Study Plan: Wheeled vs Tracked Vehicle Study

CF: (CONT)
SIGCEN (ATZH-CDM (Mr Evans))
ORDCENSCH (ATSL-CD-CS (CW2 Perry))
JFK SWC (ATSU-CD (LTC Manning))
TACOM (AMSTA-ZE (Mr Martin))
FSTC (AMXST-CA-3 (Mr Nix))
WES (WESGM (CPT Unger))
INTEL SCH (ATSI-CD-ML (CPT Summers))
AVNSCH (ATZQ-D-CC (MAJ Stempel))
Comdt
CMLSCH (ATZN-CM-CO (CPT Hampton))
AD ARTY SCH (ATSA-CDM-W (CW4 Webb))
USAMMCS (ATSK-CML (MAJ Ansley))
TRANS/AVNLOG SCH (ATSP-CDC (Mr Coen)/ATSPQ-TW (Mr Diggs))
FASCH (ATSF-CML (MAJ Van Jordan))
ENGR SCH (ATZA-CDM (Mr Runge))
QMSCH (ATSM-CDM (SFC Prytula))
INFSCH (ATSH-CD-CS (Mr Wright))
MPSCH (ATZN-MP-CCC (CPT Smith))
ARMOR SCH (ATSB-CD-ML (CPT Grice))
Dir
TORA (ATOR-TA (Mr Shook))
AMSAA (AMXSY-CM (Mr Niemeyer))
CG
MCDEC (D024 (WO Brown))

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23651

REPLY TO
ATTENTION OF: ATCD-AC

SUBJECT: Combat Developments Study Plan: Wheeled vs Tracked Vehicle Study

HQDA (DAMO-FD)
WASH DC 20310

1. Purpose of the Study Plan. To conduct an analysis of the factors used in developing wheeled and tracked vehicle operational requirements and to lay the foundation for the development of specific criteria upon which to base future decisions regarding wheeled versus tracked vehicles. Study is being done in response to HQDA (DAMO-FD) tasking of 15 May 1984.

2. References. Message, HQDA, DAMO-FD, 151924Z May 84, SAB.

3. Terms of Reference.

a. Problem. A concern exists at the Under Secretary of the Army (USA) level that the criteria used by the Combat Developments community in defining vehicle operational requirements is not clearly delineated nor is it consistently applied. To assuage these concerns, USA requested the Army staff develop a quantifiable and defendable basis for defining future wheeled and tracked vehicle operational requirements.

b. Impact of Problem. None specifically identified.

c. Objectives.

(1) Identify the mission essential factors that should be considered when developing vehicle operational requirements.

(2) Identify the inherent engineering, mobility and cost differences between wheeled and tracked vehicles designed to perform similar missions.

(3) Identify the current uses, rationale and projected future uses of wheeled and tracked vehicles by allied, Warsaw Pact and major nonaligned nations.

(4) Lay the foundation for the development of quantifiable and defendable criteria to be used in the development of future wheeled and tracked vehicle operational requirements.

d. Scope.

(1) The study will identify the gross vehicle weight ranges where oth wheeled and tracked solutions to vehicular requirements are feasible.

(2) The study will identify the mission essential factors that ould be considered when developing vehicle operational requirements.

(3) The study will identify the differences between the wheeled and racked vehicle designs related to mobility, engineering, RAM, and life cycle ost.

(4) The study will identify the force composition, rationale for election, unique features, design innovations, and future trends of wheeled d tracked vehicle fleets of allied, Warsaw Pact, and major nonaligned tions.

(5) The study will address the desirability of substituting wheeled hicles for tracked vehicles during peacetime.

(6) The study will provide a foundation for the development of a thodology to be used by the Combat Developments community in defining future eeled and tracked vehicle operational requirements.

e. Limitations.

(1) Due to time constraints, the study will make use of existing ta. Original work will be kept to an absolute minimum.

(2) The study will generate generic recommendations on the future irection of wheeled and tracked vehicle requirements definition. The study ill not make any recommendations on specific systems currently under velopment.

f. Assumptions. None.

g. Essential Elements of Analysis (EEA).

(1) What are the inherent mobility differences between wheeled and racked vehicles designed to perform similar missions in the following areas? alysis should be performed across the gross vehicle weight spectrum where oth wheeled and tracked solutions to vehicle requirements are feasible and ldress the various probable terrain types that will be encountered by US Army rces. Additionally, the analysis should address any other factors (e.g.,

visibility) that influence operational effectiveness from a mobility perspective.

(a) Soft soil mobility.

(b) Slope traversing.

(c) Obstacle negotiation.

(d) Linear feature traversing.

(e) Average cross country speed.

(f) Average road speed.

(g) Percent terrain denial.

(h) Gap crossing.

(i) Trailer towing.

(j) Vehicle agility.

(2) What are the inherent design/engineering differences between wheeled and tracked vehicles designed to perform similar missions in the following areas? Analysis should be performed across the gross vehicle weight spectrum where both wheeled and tracked solutions to vehicle requirements are feasible.

(a) Vulnerability.

(b) Interior volume.

(c) Interior vibration level.

(d) Interior noise level.

(e) System reliability.

(f) Petroleum, Oil and Lubricants (POL) consumption.

(g) External noise signature.

(h) Vehicle thermal signature.

(i) Vehicle radar signature.

(j) Transportability.

(k) Drive train and suspension volume.

(l) System maintainability.

(m) Vehicle acceleration.

(n) Payload capacity.

(o) On board power generation capability.

(p) Swimming/fording capability.

(q) Stability as a weapons platform.

(3) What are the inherent differences in cost between wheeled and tracked vehicles designed to perform similar missions in the following areas? Analysis should be performed across the gross vehicle weight spectrum where both wheeled and tracked solutions to vehicle requirements are feasible.

(a) Research, Development, Test and Evaluation (RDT&E).

(b) Procurement.

(c) Operation and Support.

(d) Life Cycle.

(4) What factors were considered critical when wheeled and tracked vehicle operational requirements were developed in the past?

(5) What is the feasibility and desirability of substituting wheeled vehicles for tracked vehicles in the training base?

(6) Are there any short distance mobility enhancements for wheeled vehicles that should receive additional development?

(7) Is it desirable to revive the half-tracked vehicle concept for further development?

(8) Do wheeled or tracked vehicles cause greater detrimental effects to on board electronic equipment through vehicle induced shock and vibration?

(9) Do wheeled or tracked vehicles induce greater operator/passenger fatigue when performing similar missions?

(10) What are the factors inherent in vehicle design that enhance operational effectiveness on the battlefield?

(11) What are the general mission roles supported by wheeled and tracked vehicles?

(12) What general mission profiles should be considered when an evaluation is made of a wheeled or tracked vehicles ability to support various mission roles (identified in EEA g(11))?

(13) Are there any mission roles (identified in EEA g(11)) that should be performed exclusively by either wheeled or tracked vehicles.

(14) What is the current vehicle mix, underlying rationale and probable future direction for the wheeled and tracked vehicle fleets of allied, Warsaw Pact, and major nonaligned nations.

(15) What factors should be considered when developing quantifiable and defendable criteria upon which to base future decisions on vehicle operational requirements?

h. Constraints. The target date for production of an executive summary with accompanying written briefing is 31 Oct 84.

i. Alternatives. Alternative vehicle concepts will be selected across the gross vehicle weight spectrum and mission roles (Combat, CS, & CSS) where wheeled and tracked solutions are considered feasible. The analysis will make use of historical performance and cost data from various vehicles, but the results of the study will be presented from a generic wheeled and tracked vehicle perspective. The analysis will make extensive use of the data generated in the Light Armored Vehicle (LAV), the Mobile Protected Gun System (MPGS), and the Armored Combat Vehicle Technology (ACVT) programs. The cost analysis will make use of the cost data generated for the five vehicles (V-150, V-300, MOWAG, Scorpion and Alvis Infantry Fighting Vehicle) of the LAV program, the HEMMT, the MLRS chassis, the FAASV and any other representative vehicles for which validated cost data is available.

j. System Organization. None.

k. Mission Profile. Various general mission profiles will be identified in EEA g(12) that will serve as the basis of the comparative analyses in phase II of the study effort.

l. Measures of Effectiveness (MOE). The objective of this analysis is to identify the critical operational factors that should be considered in developing future vehicle operational requirements. The primary MOEs of the analysis will be an identification of the critical factors (evaluated in the EEAs) that affect a wheeled or tracked vehicles ability to successfully support the various mission profiles identified in EEA g(12).

m. Methodology.

(1) The study will be conducted in two phases. Phase I will serve as the source data for phase II.

(a) Phase I.

(aa) Mobility Assessment. The US Army Corps of Engineers Waterways Experiment Station (WES) will conduct a detailed analysis of the relative mobility differences inherent in the designs of wheeled and tracked vehicles. The analysis will identify mobility differences across the weight spectrum where wheeled and tracked solutions to vehicular requirements are deemed feasible. The analysis will be a compendium of past work at WES tempered with professional judgment. The analysis will provide a general delineation of the inherent strengths and weaknesses of the two vehicle configurations from a mobility perspective. WES is responsible for answering the following EEAs: g(1)(a) thru g(1)(j), g(6), g(7), g(8), and g(9).

(bb) Design/Engineering. The US Army the Tank and Autcmotive Command (TACOM) will develop a detailed analysis of the relative engineering differences inherent in the wheeled and tracked design philosophies. TACOM will develop as complete a rationale as possible of the RAM differences between the two design configurations based on historical experience. Additionally, the analysis will address the specific survivability and transportability differences inherent in the two design philosophies. TACOM is responsible for answering the following EEAs: g(2)(a) thru g(2)(q), g(6), g(7), g(8), g(9) and g(10).

(cc) Cost. Headquarters US Army Training and Doctrine Command (TRADOC) will conduct a parametric cost analysis to identify the inherent differences in system costs between wheeled and tracked vehicles. The

analysis will make extensive use of the cost data from the LAV program and any other validated cost data that can be acquired. HQ TRADOC is responsible for answering the following EEAs: g(3)(a) thru g(3)(d).

(dd) Requirements. The TRADOC Integrating Centers, in conjunction with the TRADOC Schools will: identify the factors used in the past in developing vehicle operational requirements, identify the factors considered to be critical to battlefield effectiveness, develop mission profiles to be used in evaluating the capability of wheeled or tracked vehicles to support various mission roles, and identify general classifications for the various vehicular mission roles. TRADOC Integrating Centers are responsible for answering the following EEAs: g(4), g(5), g(10), g(11), g(12), and g(13).

(ee) Foreign Governments. The Foreign Science and Technology Center (FSTC) will perform an analysis to identify force composition, rationale for development, unique features, design innovations and future trends of the wheeled and tracked vehicle fleets of allied, Warsaw Pact and major nonaligned nations. FSTC is responsible for answering EEA: g(14).

(b) Phase II. HQ TRADOC will integrate the results of the Phase I efforts into a coherent package to identify the critical factors inherent in the wheeled and tracked vehicle design philosophies that affect vehicle operational effectiveness and should be considered when wheeled and tracked vehicle operational requirements are developed. This will be accomplished by a comparison of the inherent differences in wheeled and tracked vehicles identified in phase I (EEAs g(1) thru g(11)) in conjunction with an evaluation of the effectiveness factors and mission profiles identified in EEAs g(12) and g(13). HQ TRADOC will identify areas where data voids on the wheeled versus tracked issue exist or where additional analysis may be required to facilitate the development of a quantifiable and defendable criteria to support development of future wheeled and tracked vehicle operational requirements. Additionally, HQ TRADOC will do a comparison of the utilization of wheeled and tracked vehicles by the US Army and major foreign governments identified by FSTC in EEA g(14). HQ TRADOC is responsible for answering EEA: g(15).

n. Models. Army Mobility Model (AAM).

o. Related Studies. The analysis will be base on existing data extracted from numerous related studies. The specific studies consulted will be delineated in the bibliography of the final report.

p. Criterion of Choice. None.

4. Environmental/Threat Considerations. Vehicle capabilities will be evaluated across the environmental spectrum expected to be encountered by US Army forces. Threat will be considered from a system survivability/ vulnerability perspective.

5. Support and Resource Requirements.

a. Support Requirements.

(1) Headquarters US Army Materiel Command (AMC). Provide HQ TRADOC the life cycle cost estimates for following vehicles identified by TACOM as representative of the wheeled and tracked vehicle fleets in the gross vehicle weight categories where wheeled and tracked solutions to vehicular requirements are feasible.

(a) Wheeled Vehicles. Light Armored Vehicle (LAV) alternative vehicles (V-150, V-300, and MOWAG) and HEMMT.

(b) Tracked Vehicles. MLRS Chassis or FAASV, LAV alternative vehicles (Scorpion light tank and Alvis Infantry Fighting Vehicle).

(2) US Army Tank and Automotive Command (TACOM). Perform an analysis to identify the relative engineering differences inherent in the two design philosophies. The analysis will include an excursion into what is known about the relative differences between wheeled and tracked vehicles on various RAM, survivability, and transportability characteristics.

(3) Foreign Science and Technology Center (FSTC). Perform an analysis to identify the status of wheeled and tracked combat vehicles in allied, Warsaw Pact, and major nonaligned nations. The presentation will include a description of the present force composition, explanation of what economic or doctrinal factors led to the present vehicle fleets, and a discussion of the probable direction of foreign governments' vehicle fleets in the future with an accompanying rationale.

(4) US Army Corps of Engineers Waterways Experiment Station (WES). Perform an analysis of the relative differences between wheeled and tracked vehicle design philosophies from a mobility perspective. The analysis will include an excursion into various mobility enhancements that could be effected on wheeled vehicles to improve their mobility.

(5) Headquarters US Army Training and Doctrine Command (TRADOC). Will provide overall coordination for the analysis effort. Perform the required cost analysis using data provided by HQ AMC. Present the results of

the analysis effort to HQDA. Develop and publish a final report of the studies findings.

(6) US Army Combined Arms Center (CAC). Delineate the critical factors used in the past for the development of wheeled and tracked vehicle operational requirements by the CAC Schools. Develop a CAC position on the feasibility and desirability of substituting wheeled vehicles for tracked vehicles in the training base. Develop a CAC position on the factors inherent in a vehicle's operational capabilities that serve to enhance its battlefield operational effectiveness for the various vehicular mission roles within the center's mission areas. Develop general mission profiles to be considered when evaluating the capability of a wheeled or tracked vehicle to support the various vehicular mission roles in the center's mission areas.

(7) US Army Logistics Center (LOGC). Delineate the critical factor used in the past for the development of vehicle operational requirements by the LOGC Schools. Develop a LOGC position on the feasibility and desirability of substituting wheeled vehicles for tracked vehicles in the training base. Develop a LOGC position on the factors inherent in a vehicle's operational capabilities that serve to enhance its battlefield operational effectiveness for the various vehicular mission roles within the center's mission areas. Develop general mission profiles to be considered when evaluating the capabilities of wheeled or tracked vehicles to support the various vehicular mission roles in the center's mission areas.

b. Resource Requirements.

(1) Level of Effort.

(a) HQ AMC	30 manhours
(b) TACOM	500 manhours
(c) FSTC	500 manhours
(d) WES	1280 manhours
(e) HQ TRADOC	1000 manhours
(f) CAC	300 manhours
(g) LOGC	100 manhours

(2) Funding. Transfer of $49,950 from HQ TRADOC to WES to cover industrial funding requirements for their support of the study effort.

6. Administrative.

a. Study Schedule. The following time schedule will be used for prosecution of the study.

(1) Draft Study Plan	10 Aug 84
(2) Approved Study Plan	31 Aug 84
(3) Complete Phase I	30 Sep 84
(4) Complete Phase II	12 Oct 84
(5) Draft Briefing	19 Oct 84
(6) Approved Briefing	26 Oct 84
(7) Brief HQDA	31 Oct 84

b. Study Advisory Group (SAG). HQ TRADOC will host and chair a SAG to review the results of the analysis effort.

c. Study Project Officer. Mr Kenneth L. Boyd, ATCD-AC, AV 680-3037, FTS 931-3037.

7. Correlation. ACN 070846.

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