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Report AMCA-70-005

GROUND EFFECT VEHICLES IN OVERLAND OPERATIONS
LAND COMBAT SYSTEM-90

Ad Hoc Working Group No. 9

March 1970

Final Report

U.S. ARMY
ADVANCED MATERIEL CONCEPTS AGENCY

30

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ABSTRACT

This report documents the efforts of the Ad Hoc Working Group (AHWG) on Ground Effect Vehicles (GEV) in Overland Operations that was held by the US Army Advanced Materiel Concepts Agency in November 1969. The purpose of the AHWG was to estimate the state of the art and future 1990 characteristics and capabilities of potential GEV technology in an overland environment. Participants were selected from Government and Industry.

General conclusions reached were:

- Overland use is a new GEV environment in its own right, and will require government R&D sponsorship to develop its true potential.
- The GEV could provide an improved mobility capability as well as high speed in cross-country movement, but may require ground contact for gradeability and control and improved skirt systems for high speeds in order to exploit this performance potential.
- Roadability will require a narrow width vehicle (reducible on wide vehicles), but narrow widths could reduce obstacle clearance or degrade stability and speed.

A family of five different functional type vehicles was identified. The performance capabilities of the vehicles and the outline of an R&D program to achieve these capabilities was developed.

PREFACE

This report of the Ad Hoc Working Group (AHWG) on Ground Effect Vehicles in Overland Operations is part of a study effort being conducted by the Mobility Task Group, Exploratory Evaluation Division of the US Army Advanced Materiel Concepts Agency (USAAMCA).

The purpose of the AHWG was to estimate the state of the art and future 1990 characteristics and capabilities of potential GEV technology in an overland environment.

The USAAMCA acknowledges the valuable contributions of all the participants in the AHWG and in particular, those of Dr. Clive G. Whittenbury, Vice President of the Research Analysis Corporation, who served as Chairman of the AHWG.

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SECTION I
INTRODUCTION

1. Background

Since the end of World War II, the US Army has sought ways and means of improving and extending its battlefield mobility capability, and in the last few years it has given increasing attention to the matter of mobility capability in regimes of marginal terrain. Great mobility advances have been made possible by the concept of air mobility and its use of fixed-wing and rotary-wing aircraft. At the same time, modest improvements in surface mobility capabilities have stemmed from engineering development of conventional wheeled and tracked vehicles, and from new concepts such as articulated wheeled and tracked vehicles.

Helicopters have proven themselves in military operations and have shown major advantages in tactical operations that would have been very difficult with fixed-wing aircraft and/or tracked and wheeled vehicles. Helicopters are, however, expensive, fuel-consuming, require highly skilled operational and maintenance personnel, and lack some desirable operational capabilities of ground vehicles.

Present-day ground vehicles utilizing wheels and tracks, although they have been improved, suffer from definite mobility limitations, and projected improvements indicate no significant breakthrough in the foreseeable future which could eliminate or greatly reduce those limitations.

The Ground Effect Vehicle (GEV) however, offers a candidate vehicle which could overcome many of these limitations and could, therefore, present the Army with a significant increase in ground mobility. This vehicle, in principle, could operate cross-country at high speeds, with amphibious capabilities for operation over extremely weak soils and/or water at high speeds. Such capability would exist because the vehicle is supported by a layer of practically frictionless air and does not require physical contact with the ground to support its weight in its operational mode.

As development of the GEV progressed, primarily in foreign countries, interest in military uses of such machines increased, and performance claims listed great advantages to be gained from employment of ground effect principles. Aerospace-oriented firms in the United States, military planning and operational personnel, and maritime personnel became interested. Military operational concepts of the future began to include discussions of concepts of warfare employing vehicles utilizing these principles. Meanwhile, commercial machines have been developed and put into limited service. A number of existing commercial

GEV's have been modified (not designed especially) for specific military purposes and were used by both the US Navy and the US Army in South Viet Nam.

Overland operation in typical cross-country terrain is one of the most difficult types of operation which might be imposed upon a GEV. A great variety of surface roughness conditions would be imposed by such operations, while simultaneously requiring great maneuverability. The surface roughness would be represented by many obstacles and surface discontinuities, with abrupt rate of change of conditions. Little quantitative information on these characteristics is documented. The GEV operates very close to the surface and its potential performance capabilities are sensitive to the geometrical characteristics of the surface and the occurrence of obstacles, particularly to those natural and cultural micro-relief features from a scale of five meters on down.

2. Objectives and Scope

In light of the general interest being shown, because the Army has been doing little toward development of such vehicles despite a growing interest, the unevaluated claims of enthusiasts, and because of the continuing urgent desire for markedly increased combat mobility capabilities in future Land Combat Systems, the US Army Advanced Materiel Concepts Agency decided to undertake a study of the GEV. The objective of the study is to investigate the overland capabilities of the GEV and, if such vehicles appear to be plausible and of benefit to the Army, to propose GEV advanced materiel concepts and recommend appropriate research and development emphasis. The scope of the program is limited to consideration of the use of the GEV in overland operations (including inland waterways) and does not include investigations of open sea or ocean operations. Part of this study effort involved convening an Ad Hoc Working Group (AHWG) composed of people knowledgeable in this field from Government and Industry (see appendix) to delineate the existing state of the art and to estimate future capabilities and propose concepts of materiel using these estimated capabilities.

3. Report Outline

This report documents the efforts of the AHWG and is composed of four basic sections:

- Individual configuration and performance characteristics present and predicted for 1990.
- Vehicle concepts.
- Areas of Research and Development (R&D) necessary to achieve the predicted 1990 characteristics.
- General conclusions.

SECTION II
CONFIGURATION AND PERFORMANCE CHARACTERISTICS, AND COST DATA

Ten factors involving configuration and performance characteristics, and cost information were selected as being essential in any examination of present-day characteristics and future possibilities for GEV's, because of the import of these factors to the user and to the research and development community.

Three quantitative statements were arrived at for each factor of importance; (1) a consensus of what can be achieved with 1969 technology, (2) that which, with a reasonably good measure of expectation, can be achieved by 1990 with some R&D by defense agencies and with continued effort on the part of industry for commercial use and (3) that which might be achieved by 1990 by application of a vigorous R&D program by the Department of Defense.

1. Payload to Gross Weight Ratio

1969	- 0.35 lbs	Payload/lb of gross weight
1990 probable	- 0.55 lbs	Payload/lb of gross weight
1990 possible	- 0.65 lbs	Payload/lb of gross weight

The measure of the amount of payload (PL) that can be accommodated related to the gross vehicle weight (GVW) is an expression of structural efficiency and implied operating economy. Most vehicle requirements documents exhort the developer to seek higher and higher PL/GVW ratios. In the case of GEV's, the payload fraction is important because of the relatively high power requirements per pound of total weight to be moved and the resulting high rate of fuel consumption.

Three areas for weight reduction are very important; structural design, air cushion pressures, and use of light-weight structural materials.

a. Structural Design

In order to rationally reduce the vehicle weight, a prime requirement is adequate operating loads and the related structural stress data design for the type of situations the vehicle will encounter. Such data is presently non-existent for design purposes for application to a GEV operating in an overland environment.

b. Cushion Pressure

Present vehicles operate with cushion pressures in the range of 30 to 50 pounds per square foot. Cushion pressure determines the planform of the vehicle which in turn affects the structural design and weight. Increased cushion pressure would reduce the planform area and possibly the structural weight, but, again, little or no data is available on design criteria for operating at higher cushion pressures. Cushion pressure effects on stability, obstacle-clearance capabilities, power requirements, movement of debris, and other aspects of operation must also be determined.

c. Light Weight Materials

The manufacturing techniques and the application of glass reinforced plastics are presently under investigation as one means of cutting down the weight as well as the cost of the GEV. The use of inflatable structures is another means of weight reduction that has been proposed. Use of inflatable structures may also be a promising means of reducing size as well as weight.

2. Thrust per Horsepower

1969	-	3 to 5 lbs/shaft horsepower
1990 probable	-	5 to 7 lbs/shaft horsepower
1990 possible	-	15 to 25 lbs/shaft horsepower

Air propellers and high volume discharge of part of the cushion air supply are the present means of developing thrust. Major efforts in propeller design have been centered around aircraft usage and, as a result, their design has been optimized for the higher speeds of the aircraft as compared to the relatively lower speeds of the GEV. Possible means of increasing air thrust would be high solidity propellers, cycloidal or wave propellers, more efficient use of high volume low velocity discharge of air and less complex turbines optimized for the GEV load spectrum. Ground contact thrust systems would offer considerable thrust-to-horsepower ratios for low speed operations.

3. Obstacle Height to Beam Ratio

1969	-	0.15 obstacle ht/beam
1990 probable	-	0.25 obstacle ht/beam
1990 possible	-	0.50 obstacle ht/beam

Obstacle-clearing capability of a GEV is dependent upon a number of considerations, the most conventional being the depth of a flexible skirt below the hard structure. The depth of the flexible skirt in turn dictates the beam of the vehicle in order that stability can be maintained in today's vehicle concepts.

Achievement of the 1990 probable figure of 0.25 is dependent upon evolutionary development of new design of, and materials for, skirts, and compartmentation of cushion air. Achievement of a 0.50 ratio might result from a concentrated vigorous R&D effort in variable - geometry skirts, multiple-state variable stiffness skirts, terrain - anticipation systems coupled with sophisticated skirt-retraction or movement systems, and/or differential compartmented cushion pressure systems.

4. Step Obstacle Crossing

1969	-	6 feet
1990 probable	-	30 feet
1990 possible	-	50 feet

Six feet is the maximum height obstacle that can be crossed with the largest GEV in existence today. To overcome higher obstacles, the vehicle would have to crawl over the obstacles or operate out of ground effect. The latter could be achieveable by use of reaction jets, low aspect ratio inflatable wings, or by rotation of some type of lifting device such as a rotor. With such devices a GEV could be given a high obstacle clearance capability for a short period, or a capability for a series of such "jumps", each of short duration.

It must be pointed out that, for stability reasons, and with current design concepts in ground effect operations, the height of obstacle-clearance that can be achieved is almost completely dependent upon the beam width of the vehicle.

5. Slope Climbing Capability

1969	-	10% to 14% continuous slope
1990 probable	-	15% to 20% continuous slope
1990 possible	-	60% continuous slope

Slope climbing capability is related to weight of the vehicle and the thrust achieved. Limitations of current GEV designs in cross slope operation are particularly severe. The 1990 probable slope-climbing-capability is dependent upon achievement of high thrust output per installed horsepower, and lighter weight vehicles. The 1990 possible capability of 60% slope climb could be achieved by some means of variable height ground contact to augment the thrust, by advanced efficient aerodynamic thrustors, or winching. Variable height ground-contact devices for SEV's could add complications, weight, and maintenance. When used simply for control purposes, ground contact devices would not necessarily be subject to the same soil deformation problems as in the case of contact support or thrust systems since the control and stability systems need not support the vehicle (since the vehicle would be supported primarily by the air cushion.)

Tractive effort, obtained by ground contact systems relying on surface friction, depends on the pressure exerted by the ground contact device and the characteristics of the soil. A GEV using this system would have capabilities similar to a wheeled or tracked vehicle - if that were the ground contact system used - on firm surfaces. In weak soils the wheeled or tracked vehicles have not only the problem of developing thrust due to the nature of the soil but can also sink or dig itself into a hole. The GEV would avoid this digging in and would get some - albeit limited - thrust reaction from the soil.

6. Deceleration on Cushion

1969	- 0.1 g to 0.25 g
1990 probable	- 0.5 g
1990 possible	- 1.0 g

Control of GEV's, including deceleration, poses considerable problems at present. To decelerate, present vehicles depend on reversing the thrust of the air propulsors or by dumping lift and settling on the deflated skirt. Improvement in propulsor effectiveness and possible use of cushion air pressure can provide limited additional deceleration capabilities. The 1990 predicted values may require some sort of positive ground contact mechanism acting as brakes to markedly improve deceleration capabilities. Ground contact devices with efficient braking capabilities and improved reverse propulsors and thrusters coupled with reduction of the air cushion lift during braking may all be necessary to approach the 1990 possible value. Even low levels of deceleration capability on descending slopes may require ground contact devices in addition to improved reverse thrust capability. The use of ground contact devices will dictate the investigation of overturning moments (tendency to flip) of the vehicle when operating on cushion due to the vehicles possibly high center of gravity (c.g.). This problem would be critical on small vehicles with high obstacle clearance capability (high c.g.).

7. Engine Specific Fuel Consumption

1969	- 0.65 lbs of fuel per Horsepower Hour
1990 probable	- 0.43 lbs of fuel per Horsepower Hour
1990 possible	- 0.37 lbs of fuel per Horsepower Hour

A majority of present GEV engines are aircraft turbines. The complexity (altitude compensation, etc.) and safety built into these engines are not required for a GEV but due to the high volume production and the small size and light weight, this engine has been used in present vehicles. The predicted possible specific fuel consumption is based on a turbine engine with regeneration.

8. Velocity with Adequate Habitability

	1969	1990 Probable	1990 Possible
Smooth Surface (MPH)	75	100	200
Moderate Terrain Roughness (MPH)	45	80	150

Habitability of the craft is dependent upon isolation or attenuation of the ground disturbance loads within human factors tolerances. Possible means of achieving adequate habitability over rough ground would be modulating or controlling the cushion pressure, compartmentizing or controlling the skirt system and isolation of the crew through the use of energy absorbing devices.

9. Velocity to Turn Radius Ratio

1969 - 0.30 - 0.05 ft per sec/ft
1990 - comparable to a wheeled vehicle

Present vehicles use skirt lift, puff ports and rudders in the propeller air stream to control the direction of the vehicle when operating over land. To achieve turning radius comparable to a wheeled vehicle, some means of ground contact must be utilized.

10. Noise

1969 - 75 to 100 db at 500 ft
1990 probable - 70 db at 500 ft
1990 possible - 65 db at 500 ft

The main source of noise on present vehicles is the propeller and the turbine engine. Agressive efforts to cut the turbine noise as well as propeller noise reduction efforts must be undertaken.

11. Cost

	1969	1990 Probable	1990 Possible
Initial Cost ($ per lb empty)	$20 to $40	$15	$5 to $10

Present GEV cost must be related to the small number of craft built, the techniques used in manufacture and the powerplant used. The cost of the vehicles will come down as the quantities of vehicles increase. Present craft have been built utilizing aircraft techniques by aircraft manufacturers and aircraft turbine engines as the powerplant. The increased use of the turbine engine in the automotive and marine field may provide the GEV builder with a more economical powerplant. Use of lower cost material and mass production manufacturing techniques will also help to cut the costs.

SECTION III
VEHICLE CONCEPTS

In order to take advantage of the existing and projected capabilities as described in Section II, a family of vehicles utilizing an air cushion as the suspension medium was conceived. The performance characteristics are what is envisioned as needed by each particular type of vehicle to satisfy general mission requirements.

1. Terminology

a. Roadability - In order to meet this requirement, the vehicle width must be capable of being reduced to 10 to 12 feet and height of less than 14 feet. Vehicle width affects stability and hence, speed. The speeds indicated as required are for a vehicle at its normal width and using ground contact for control. The desired speeds are for vehicles with reduced width and ground contact.

b. Obstacle Clearance - The height specified is the height of a step obstacle. (The obstacle could be as wide as the vehicle or wider.)

c. Turning Radius - Turning radius is expressed in units of acceleration and is the acceleration toward the axis of the turn necessary to keep the vehicle moving in a circle about that axis. The following table gives the turning radius for different speeds and values of acceleration:

Speed (mph)	Acceleration (g's)	Radius (ft)
20	.05	534
20	. 1	267
20	. 3	89
60	.05	4,840
60	. 1	2,420
60	. 3	806

d. Dash Speed - Speed the vehicle is capable of attaining for short periods of time at maximum thrust.

e. Cruise Speed - Normal continuous operating speed for the vehicle.

f. Acceleration - Positive time rate of change of velocity or speed in the direction of motion.

g. Slope - Ratio of the climbed or descended height to the projected horizontal distance expressed as a percent. Infinite capability means a vertical or jump capability.

h. Overall Height - Overall height of the vehicle when operating on the cushion.

i. Noise - Volume of the sound produced during operation (does not include weapon firing noise).

j. Reliability - Mean time between failures of the major components.

k. Environmental - The weather conditions in which the vehicle should be capable of operating.

l. Installed Weapons - Weapons provided as an organic part of the GEV.

m. Armor Protection - Material either added to or a structural part of the GEV or worn by the crew to improve survivability.

2. Scout Vehicle

VEHICLE CHARACTERISTICS

CHARACTERISTICS	REQUIRED	AVAILABLE	DESIRABLE	AVAILABLE
Roadability - mph	20	1975	60	1990
Obstacle Clearance - ft	4	1975	Over 20	1990
Turning Radius (on cushion)	0.1g	1975	0.3g	1990
Dash Speed - mph	None Req.		100	1990
Crusie Speed - mph	60	1975	60	1975
Acceleration - g	0.25g	1980	0.5g	1990
Slopes (side & up) - %	60%	1980	Infinite	1990
Overall Height - ft	10	1980	6	1990
Noise - db at 500 ft	55	1980	Less 50	1990
Reliability - MTBF	1000 hrs	1975	1500 hrs	1990
Environmental	Wind Restrictions	1975	All Weather	1990
Installed Weapons	VRFWS*	Time Frame	VRFWS	Time Frame
Armor Protection	Crew Body	1975	7.62 mm	1990

* VRFWS - Very Rapid Fire Weapons System available in the particular time frame.

3. Combat Vehicle

VEHICLE CHARACTERISTICS

CHARACTERISTICS	REQUIRED	AVAILABLE	DESIRABLE	AVAILABLE
Rcadability - mph	20	1975	60	1990
Obstacle Clearance - ft	4	1970	Over 20	1990
Turning Radius (on cushion)	0.1g	1980	0.3g	1990
Dash Speed - mph	None Req.		75	1990
Cruise Speed - mph	60	1970	60	
Acceleration - g	0.25g	1980	0.4g	1990
Slopes (side and up) - %	30%	1975	60%	1980
Overall Height - ft	13	1975	10	1990
Noise - db at 500 ft	55	1980	50	1990
Reliability - MTBF	1000 hrs	1980	1500 hrs	1990
Environmental	Wind Restrictions		All Weather	1980
Installed Weapons	Note 1	1975		
Armor Protection	7.62 mm		23 mm	1990

Note 1: a. Vehicle operating as infantry fighting vehicle armed with VRFWS.

b. Vehicle operating as assault vehicle armed with Shillelagh type weapon.

4. <u>Combat Support Vehicle</u>

VEHICLE CHARACTERISTICS

CHARACTERISTICS	REQUIRED	AVAILABLE	DESIRABLE	AVAILABLE
Roadability - mph	20	1975	60	1990
Obstacle Clearance - ft	4	1970	8	1980
Turning Radius (on cushion)	0.05g	1970	0.1g	1980
Dash Speed - mph	50	1980		
Cruise Speed - mph	40	1970	60	1970
Acceleration - g	N/A		N/A	
Slopes (side & up) - %	30%	1980	60%	1990
Overall Height - ft	15	1970	13	1980
Noise - db at 500 ft	100	1970	55	1980
Reliability - MTBF	1000 hrs	1980	1500 hrs	1990
Environmental	Wind-limits	1970	All weather	1980
Installed Weapons	See Note 1			
Armor Protection	Crew Body	1970	14.6 mm	1990

Note 1: a. Vehicle will be armed according to employment, e.g., artillery-towed (carried on deck) or mounted howitzer, air defense gun or missile, etc,; engineer-50 caliber machine gun.

b. Will normally be able to select route.

5. Combat Service Support Vehicle

VEHICLE CHARACTERISTICS

CHARACTERISTICS	REQUIRED	AVAILABLE	DESIRABLE	AVAILABLE
Roadability - mph	20	1975	60	1990
Obstacle Clearance - ft	4	1970	8	1975
Turning Radius (on cushion)	Note 1		—	
Dash Speed - mph	N/A		—	
Cruise Speed - mph	40	1970	60	1975
Acceleration - g	Note 1		—	
Slopes (side & up) - %	Note 1		—	
Overall Height - ft	Note 1		—	
Noise - db at 500 ft	Note 1		—	
Reliability - MTBF	1000 hrs	1975	1500 hrs	1990
Environmental	Wind-limits	1970	All weather	1980
Installed Weapons	Note 1		—	
Armor Protection	None		—	

Note 1: a. Firm requirements not established, but state of the art generally acceptable.

b. May operate on improved and semi-repaired routes.

6. <u>Logistics Over the Shore (LOTS) Vehicle</u>

VEHICLE CHARACTERISTICS

CHARACTERISTICS	REQUIRED	AVAILABLE	DESIRABLE	AVAILABLE
Roadability - mph	None			
Obstacle Clearance - ft	6 ft waves	1975	12-15 ft breakers	1990
Turning Radius (on cushion)	Note 1			
Dash Speed - mph	N/A			
Cruise Speed - mph (4 to 6 ft waves)	35	1970	70	1980
Acceleration - g	Note 1			
Slopes (side & up) - %	40%	1980		
Overall Height - ft	Note 1			
Noise - db at 500 ft	Note 1			
Reliability - MTBF	1000 hrs	1975	1500 hrs	1990
Environmental	Windlimits marinized	1970	All weather	1980
Installed Weapons	Anti-air	1970	Anti-air	
Armor Protection	None		None	

Note 1: Firm requirements not established, but state of the art generally acceptable.

A version of a logistics vehicle could have installed power to operate the cushion lift system and depend on a wheeled, tracked or aerial vehicle as the prime mover. A logistics vehicle train could be built by coupling a series of vehicles together.

SECTION IV
RESEARCH AND DEVELOPMENT PROGRAM

Although the GEV's have undergone limited development toward actual operating hardware, research and development funds must be expended by the Army to develop and exploit its operational promise in an overland environment. Present programs being funded and programs proposed for funding by the US Navy as well as the Advanced Research Projects Agency (ARPA) of the Department of Defense should be investigated to insure exploitation without duplication of effort for the program presented here. The US Navy efforts to develop amphibious GEV's should provide a large portion of the R&D in support of the Logistics-over-the-Shore (LOTS) vehicle. Army efforts should involve monitoring the Navy program and initiating its own R&D program where the Navy program will not satisfy Army requirements. It was brought out by the attendees that foreign efforts have been more heavily government funded than US programs.

The proposed R&D program is broken out by systems as follows:

1. Cushion Systems

Requirement	Program
High Skirt Height/Vehicle Beam	Variable Geometry Skirts Multiple Stage Skirts Terrain Anticipation Systems Differential Cushion Pressure
Increased Stability & Habitability	Variable Stiffness Skirt Systems Terrain Anticipation Systems Multiple Stage Skirts
Low Drag	Low Inertia Designs Improved Materials Terrain Anticipation Systems

2. Controls

Requirement	Program
Braking and Turning Comparable to Wheeled Vehicles	Surface Contact Controls Improved Pylon Mounting Techniques Cycloidal/Wave Propellers

3. Power Transmission

Requirement	Program
Low Weight Systems Low Noise System Low Power Loss Systems	Improved Electric and/or Hydraulic Drive Systems

4. Structures

Requirement	Required R&D Effort
High Speed Cross-Country Travel	Experimentally Determined Load Data
Impact and Corrosion Resistant Structures	Glass Reinforced Plastic Development Structural Members Development Automated Layup Inflatable Structures
Light Weight Structures	Compliant Shock Absorber Development Inflatable Structures

5. Propulsion

Requirement	Required R&D Effort
High Thrust Per Horsepower	High Solidity Propellers Cycloidal or Wave Propellers Use of Cushion Air or Engine Thrust for Augmentation Ground Contact Propulsion
Low Noise	(Above) High Thrust Rotary or External Combustion Improved Electrical & Hydraulic Drive Systems Rotary or External Combustion Ground Contact Propulsion
Elimination of Surf Spray Ingestion	Filtration and Air Inlet Design and Location Studies

6. Out of Ground Effects

Requirement	Required R&D Effort
Obstacle Clearance Greater than 20 Feet	High Thrust Turbine Engines Low Aspect Ratio Wings Retractable Rotor and Air Cushion Suspension

Technology being advanced in other R&D programs to operate out of ground effect will be utilized as it is recognized that the required R&D effort is being performed on aircraft, propulsion systems and helicopters.

The characteristics of reliability and environmental were not identified as specific programs but would naturally result from other program efforts.

7. R&D Priority

The priority of the particular area of the R&D program would depend upon the particular vehicle concept selected. The table below shows tentative judgements by the AHWG on these priorities:

	LOTS	CSS	CSV	CV	SCOUT
Roadability		1	2	1	2
Obstacle Clearance	5	3	3	2	1
Turning Radius			7	5	3
Dash Speed			5	3	9
Cruise Speed	3	4			
Acceleration				6	8
Slopes	4		1	4	4
Overall Height			9	9	6
Noise			11	10	5
Reliability	2	2	4	7	7
Endurance	6	5	6	11	10
Environmental	1	6	10	12	11
Armor Protection			8	8	12

SECTION V
CONCLUSIONS

The following conclusions were reached by the AHWG:

1. Use of GEV's can provide three new operational capabilities to overland combat operations of the future.

- The capability for surface operations in areas denied to movement by foreseeable wheeled and tracked vehicles or in conditions in which wheeled or tracked vehicle mobility is limited
- The capability of high-speed cross-country operation in areas in which it can operate
- The capability of moving very heavy loads in unfavorable terrain

2. Use of GEV's in general overland operations is essentially a new and largely unexplored technological area posing many new technological problems, and requiring considerable expenditure of effort for viable solutions.

3. GEV's are expected to be complementary to more conventional ground and air vehicles and will not necessarily replace them. They may prove to be essentially special-purpose vehicles, cost-effective only in certain environments.

4. GEV's with today's design concepts will be capable of satisfactory performance in the cushion mode in specific types of operations under specific ranges of environments. To be capable of more varied operations under a wider range of environmental conditions, so as to be of more general use, some sort of ground contact devices may be required. Additionally, some means of reducing the width of the vehicle below that required for stability in the cushion mode must be achieved to allow for maneuver among obstacles and for roadability.

5. In general, materials, powerplants, and structures of GEV's have evolved from those of the aerospace industry with resultant high cost and over-optimized structural design efficiencies. Efforts in these technological areas addressed to specific usage in ground effect vehicles can lower costs and increase efficiency of operation.

6. A major and varied research and development program would be required to permit the Army to exploit GEV's advantageously (where desirable for use) in future overland operations.

7. Current Research and Development efforts without Government sponsorship are inadequate to exploit the potential of the GEV for Army operations due to the present major commercial interests being in an over water and related amphibious environments.

APPENDIX A
AGENDA
AD HOC WORKING GROUP
GROUND EFFECT VEHICLES

Tuesday - 18 November 69	0830-1130	-	Administration
		-	Purpose
		-	Background - US Army and ARPA
	1300-1600	-	GEV Technology and Vehicle Concepts
Wednesday - 19 November 69	0830-1600	-	The operational need and the exploitation of Ground Effect Technology
		-	Current Army Applications
		-	Future Concepts - Army 90
		-	Logistic Amphibious and Combat Engineering Application
Thursday - 20 November 69	0830	-	Summary and Conclusions
		-	Report Draft

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13. ABSTRACT

This report documents the efforts of the Ad Hoc Working Group (AHWG) on Ground Effect Vehicles (GEV) in Overland Operations that was held by the US Army Advanced Materiel Concepts Agency in November 1969. The purpose of the AHWG was to estimate the state of the art and future 1990 characteristics and capabilities of potential GEV technology in an overland environment. Participants were selected from Government and Industry.

General conclusions reached were:

- Overland use is a new GEV environment in its own right, and will require government R&D sponsorship to develop its true potential.
- The GEV could provide an improved mobility capability as well as high speed in cross-country movement, but may require ground contact for gradeability and control and improved skirt systems for high speeds in order to exploit this performance potential.
- Roadability will require a narrow width vehicle (reducible on wide vehicles), but narrow widths could reduce obstacle clearance or degrade stability and speed.

A family of five different functional type vehicles was identified. The performance capabilities of the vehicles and the outline of an R&D program to achieve these capabilities was developed.

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