Research Report 1434

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Human Factors Assessment: Light Armored Vehicle, Maintenance/Recovery Vehicle (LAVM/RV)

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U. S. Army
Research Institute for the Behavioral and Social Sciences

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This report describes the human factors evaluation of the Light Armored Vehicle Maintenance/Recovery Vehicle (LAVM/RV) that took place at Twentynine Palms, California, from December 1983 to April 1984. The evaluation was in conjunction with Operational Test II of the LAVM/RV conducted jointly by the Marine Corps Operational Test and Evaluation Agency (OTEA) and the Army OTEA. The report documents man-machine interface and safety problems recommended for correction before full-scale production if maximum effectiveness is to be realized.

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Human Factors in Training and Operational Effectiveness

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FOREWORD

This report presents the results of research regarding human factors, safety, and training aspects of the Light Armored Vehicle, Maintenance Recovery Vehicle (LAVM/RV). The research was conducted in conjunction with the joint U.S. Army/U.S. Marine Corps Operational Test II (OT II) held at Twentynine Palms, California, from December 1983 to April 1984. The Army Research Institute's Fort Hood Field Unit performed this research that identified numerous problem areas requiring attention before full-scale production is initiated. This evaluation is part of an ongoing ARI program of research on human factors, safety, and training aspects of Army combat vehicles and weapons systems. The findings of this research program provide information to correct the problems in future LAVM/RVs as well as input for the design of future vehicles.

EDGAR M. JOHNSON
Technical Director

HUMAN FACTORS ASSESSMENT: LIGHT ARMORED VEHICLE, MAINTENANCE/RECOVERY VEHICLE (LAVM/RV)

EXECUTIVE SUMMARY

Requirement:

The LAVM/RV was tested in Operational Test II jointly by U.S. Marine Corps Operational Test and Evaluation Agency (OTEA) and U.S. Army OTEA at Camp Pendleton and Twentynine Palms, California, from December 1983 to April 1984. This report describes the assessment support provided to the test by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) to identify man-machine interface, safety, task performance, and operator literature deficiencies requiring attention and correction.

Procedure:

Observations of two LAVM/RV crews and vehicles performing recovery scenarios at Camp Pendleton were made by a human factors specialist. Structured interviews were administered to crew members after the recovery scenarios had been completed. End-of-test questionnaires were used to assess the human factors problem areas identified during on-site observations and structured interviews.

Findings:

Human factors deficiencies were found for interior vehicle features, exterior vehicle features, and auxiliary equipment. Crewmen reported problems including using and maintaining the winch, inappropriate locations for stowage of equipment, and inappropriate provisions for loading the auxiliary power unit. Observation of crew duties revealed problems involving ingress and egress of the vehicle and workspace within vehicle crew stations.

Utilization of Findings:

This report has been delivered to U.S. Marine Corps OTEA for inclusion in the Independent Evaluation Report (IER). Incorporation of the findings should improve the operational effectiveness of the LAVM/RV. Crewman and maintainer safety should also be improved.

HUMAN FACTORS ASSESSMENT: LIGHT ARMORED VEHICLE, MAINTENANCE/RECOVERY VEHICLE (LAVM/RV)

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HUMAN FACTORS ASSESSMENT: LIGHT ARMORED VEHICLE, MAINTENANCE/RECOVERY VEHICLE (LAVM/RV)

INTRODUCTION

General

This report describes the human factors assessment of the Light Armored Vehicle, Maintenance/Recovery Vehicle (LAVM/RV). The assessment was part of the OT II conducted jointly by the US Army Operational Test and Evaluation Agency (OTEA) and the US Marine Corps OTEA at Camp Pendleton and Twentynine Palms, Marine Corps Combat Training Centers. The OT II was conducted from December 1983 to April 1984. The human factors assessment support was provided to US Army OTEA by the US Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Hood Field Unit.

The objective of the human factors assessment was to identify man-machine interface, safety, task performance and operator literature deficiencies requiring attention or correction. The outcome of the assessment is to document human factors/engineering deficiencies, in order to improve the LAVM/RV and its systems. The assessment found several deficiencies on the LAVM/RV; however, the majority of the shortcomings may be corrected without unreasonable expense and may remain within the vehicle's configuration constraints.

Description of the Vehicle

The LAVM/RV is the recovery variant of the light armored vehicle, having an eight-wheeled hull and chassis, and is shown in Figure 1. Table 1 lists many of the unique features of the vehicle. The purpose of the vehicle is to provide repair and recovery services for the light armored family of vehicles. To serve this purpose, the LAVM/RV must be able to travel as rapidly and as far as the other LAV combat vehicles. Moreover, it must be able to provide effective maintenance and recovery support at a great distance from rear area maintenance support facilities.

The LAVM/RV has 4 x 8 and 8 x 8 drive train capability. Cross-country high speed is approximately 40 mph (64.4 km), while on highways it is 70 mph (112.6 km). The vehicle crew consists of a driver, commander, rigger, and two mechanics.

The specialized features of the vehicle include:

1. HIAB Model 650 crane (L.C. 6.6 tons),
2. Braden Model AMSU-10-12 FL winch (L.C. 30,000 lbs),
3. Atlas polar auxiliary power unit/welder generator,
4. Fuel transfer pump and hoses,
5. Left and right outriggers for stabilizing during crane operations,
6. Left and right rear spades for anchoring the vehicle during winch operations,
7. Interior folding workbench,
8. Provision for oxygen/acetylene welding equipment.

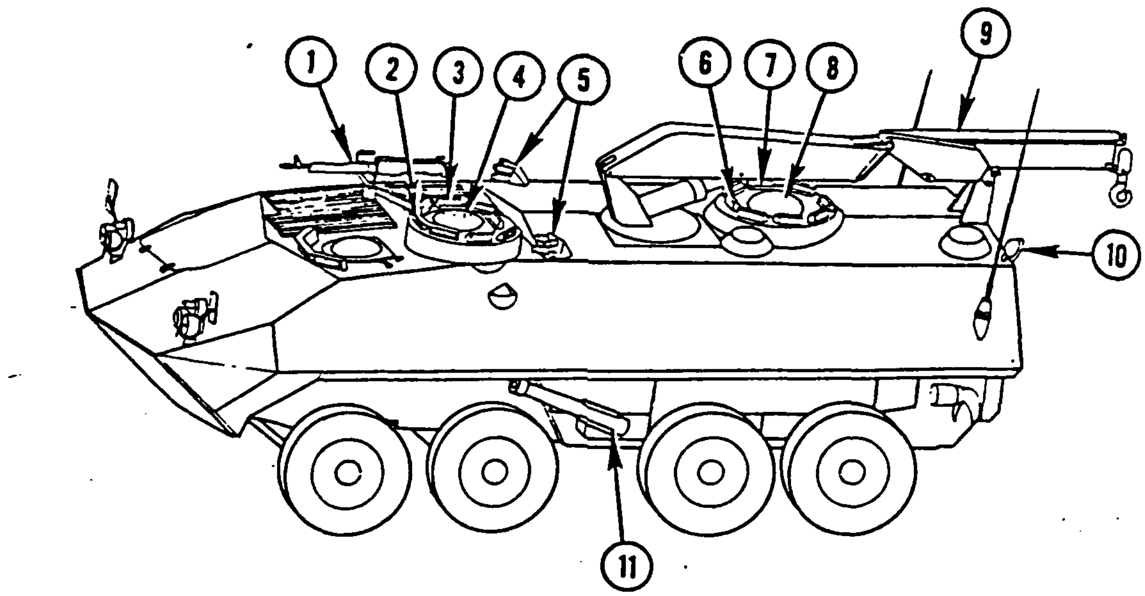

Figure 1. Location of LAVM/RV major exterior components.*
(for description see Table 1)

*Reproduced from Preliminary operator's manual supplement for recovery vehicle (LAV-25(MC)-10/R). Canadian Commercial Corporation, August 1983, p 1-0.

Table 1

Description of LAVM/RV Major Exterior Components*

Figure 1 Location No.	Description
(1)	M60-D MACHINEGUN. The machinegun is mounted above the commander's hatch.
(2)	COMMANDER'S NIGHT VIEWER. The night viewer periscope, having image intensification, can be fitted in place of a day periscope.
(3)	COMMANDER'S PERISCOPES. Eight periscopes allow the commander a 360 degree field of view outside the vehicle when the commander's hatch is closed.
(4)	COMMANDER'S HATCH. The closed hatch protects the commander from enemy fire and opens to give the commander a clear view of the terrain and access to the machinegun.
(5)	SMOKE GRENADE LAUNCHERS. Two launchers each consist of four launch tubes holding one smoke grenade each and are located on the left and right sides of the vehicle.
(6)	RIGGER'S NIGHT VIEWER. A night periscope, having passive image intensification, can be fitted in place of a day periscope.
(7)	RIGGER'S PERISCOPES. Eight periscopes allow rigger 360 degree field of view outside the vehicle when the hatch is closed.
(8)	RIGGER'S HATCH. When the hatch is closed it protects rigger from enemy fire and opens for viewing during crane operations.
(9)	CRANE. The crane is an extendable, rotatable, hydraulic knuckle boom. It can lift up to 6.6 tons.
(10)	PORTABLE FLOODLIGHT. The floodlight provides light outside the vehicle for nighttime repair/recovery operations.
(11)	OUTRIGGERS. The outriggers are used to help stabilize the vehicle during crane operations.

*Reproduced from Preliminary operator's manual supplement for recovery vehicle (LAV-25(MC)-10/R. Canadian Commercial Corporation, August 1983, pp 1-4 & 1-5.

Background

A review of the recovery literature and preliminary field observations of recovery tasks were conducted prior to the LAVM/RV human factors data collection efforts. The literature review revealed that very little has been written concerning specific recovery vehicles. This was probably due to the few recovery vehicles used by the Army and Marine Corps and to the support role in which they have been used. The most widely used, land based military recovery vehicles include:

1. The 5-ton recovery truck,
2. The M578 tracked, medium recovery vehicle,
3. The AMTRAC LVTR7 tracked, amphibious recovery vehicle, and,
4. The M88 tracked, heavy recovery vehicle.

The review did, however, find that these recovery vehicles do have similar human factors deficiencies (Daily & Brunet, 1973; Martinson, Lahman, & Creighton, 1973; and Holt, Glasgow, Hevr, Miller, & Cunningham, 1983). Many of the deficiencies were also found during the OT II test of the LAVM/RV and include:

1. Controls were not labeled or had labels that were not legible; this was also a problem found for controls of auxiliary equipment such as cranes, winches, and Auxiliary Power Units (APUs),
2. The hatch securing mechanisms and seals were continually bent or broken,
3. The ventilation systems were poor for high dust, hot environments,
4. The storage space was extremely limited,
5. The noise levels were high inside and outside of the vehicles,
6. Steps, handholds, footholds, and walkway surfaces were often extremely slippery,
7. Heavy auxiliary equipment was stored high on the vehicle, making handling of the equipment difficult,
8. The operator literature was insufficient or incorrect.

Some of these recurring design deficiencies were significant, especially when considering that recovery vehicles and crews are usually called upon to operate in the worst of environmental conditions; conditions that have trapped or stopped the operation of other vehicles. The human factors engineering deficiencies probably recurred for two reasons. First, human factors engineering was not given enough priority early in the conceptual design phases of the recovery vehicle. Second, there were no human factors MIL standards (1472C) specifically addressing the unique design of recovery vehicles.

Preliminary field observations were made of various recovery tasks and vehicles at Fort Hood, Texas, in order to confirm or extend the findings of the literature. Several observations of the vehicles were relevant to the human factors assessment of the LAVM/RV and include:

1. Recovery crews work together on most tasks, regardless of crew positions. This is unlike combat vehicles where tasks and crew positions are specialized. Thus, all crew members generally have experience using all of the equipment of the recovery vehicle.

2. The mission of the recovery vehicle includes numerous unique tasks. For example, removing a turret is a very different task than is recovering a mired vehicle. Towing is a very different task than is fuel transfer.

3. The crew and vehicle must be prepared for a variety of tasks and conditions in the field. During operations the LAVM/RV crew may not know the actual condition of the vehicle in need of support until they arrive on site.

4. Recovery under combat conditions may involve special problems. One problem facing the crew is the need for self defense which will divide the attention of the commander and driver. Recovery tasks must then be performed in less time than would normally be desirable. NBC defense (and decontamination) will involve the use of MOPP gear which may hinder recovery operations. Finally, in combat the LAVM/RV may be required to support vehicles other than the LAV combat vehicles. These factors were difficult, and sometimes impossible, to examine during the LAVM/RV OT II.

METHOD

Crew Members

Two crews and two identical LAVM/RV vehicles were tested. The two vehicle crews consisted of five members each. Nine members were male while one was female. One vehicle was manned by USMC personnel while the other was manned by US Army personnel. The five crew positions in each vehicle included a commander, driver, rigger, and two mechanics. Nine crew members had recovery experience prior to the test (mean years of experience was 1.7 years). One crew member had a 65 percent hearing loss in one ear; otherwise, no one reported any physical abnormality that might have influenced the assessment results. Other biographical data is summarized in Table 2.

Assessment Materials

A questionnaire and structured interviews were developed for data collection during the LAVM/RV OT II and served to complement each other. The questionnaire was designed to investigate human factors considerations pertaining to the LAVM/RV and its equipment. Additionally, the structured interviews were designed to investigate human factors considerations pertaining to the operations and tasks performed during recovery scenarios. The questionnaire and structured interviews were designed to be administered to all crew members as all crew members tend to pitch in and help on all tasks and use all vehicle equipment. The complete set of data collection materials and raw data are contained in the ARI Research Note: LAVM/RV OT II Human Factors Assessment Materials (Krohn, in preparation).

The questionnaire contained 70 questions and many questions involved several items requiring a response to each item. Two five-point rating scales and a Yes/No checklist were used. One scale had descriptors and numerical values ranging from "very adequate" (5) to "very inadequate" (1) while the other scale had descriptors ranging from "very easy" (5) to "very difficult" (1). The Yes/No checklist was used to identify hazards associated with equipment. All items had sections for respondent comments or to indicate that the question was not applicable to them. The types of scales used were limited to two similar scales requiring the same type of response in order to:

Table 2

Summary of Biographical Data[a]

Commander	Age (years)	Time in Service (years)	Primary MOS	Time in PMOS (years)
USMC Commander	25	6.00	2142	5.75
USA Commander	28	9.75	63H10	1.00
All Crew Members	Mean, 24	Mean, 5.2	2142 (4)[b] 1316 (1)	Mean 2.7
	Range, 20 to 28	Range, 2.25 to 9.75	63H10 (4) 63H20 (1)	Range, 1 to 6
	<u>Heights</u>		<u>Weights</u>	
All Crew Members	Mean, 75.2 in. Range, 52 to 76 in.	 191 cm 132 to 193 cm	Mean, 174.8 lb. Range, 135 to 218 lbs.	 79.3 kg 98.8 kg 61.2 to 98.8 kg

[a]Acronyms:
MOS; Military Occupational Specialty,
PMOS; Primary Military Occupational Specialty.

[b]Number of crewmen having MOS.

1. Simplify and limit the required length of the questionnaire instructions,
2. Simplify and limit the type of required responses,
3. Eliminate the need to display a scale for each question and to decrease required page space,
4. Simplify and standardize page format.

During the administration of the questionnaire, the respondents neither reported nor appeared to have any difficulty responding to the questionnaire items. The questionnaire was divided into two sections. The total time to administer the questionnaire was one hour and 45 minutes including a brief break between sections.

The structured interviews were developed using a Yes/No checklist format with space to record interviewee comments. A separate structured interview was conducted for each type of major recovery scenario performed during the human factors assessment. The interviews focused on general topics concerning all scenarios, the specific equipment used during a scenario, and the tasks performed. Each interview lasted approximately 30 minutes.

Assessment Procedures

The sequence of the LAVM/RV human factors assessment activities is shown in Figure 2. Initial coordination meetings were conducted with the US Army OTEA human factors project officer and the project data manager at Falls Church, Virginia, in September 1983. The initial scope of the project was discussed and it was recognized that the design of the data collection materials would have to account for the variety of scenarios to be conducted. In December 1983, data collection efforts were reviewed and coordinated at the USMC Combat Training Center, Twentynine Palms, California. At the meeting data collection materials were reviewed, site visit dates were set, and test controllers and RAM data collectors were briefed on how they could contribute to the assessment.

Other recovery vehicles and tasks were observed and reviewed at Fort Hood, Texas, later in December 1983. Interviews were conducted with a former brigade recovery commander and two recovery specialists. Observations were made of the 5-ton recovery truck, the M578 tracked, medium recovery vehicle, and the M88 tracked, heavy recovery vehicle. The interviews and observations were used as a partial basis for the development of the structured interviews to be used with the LAVM/RV.

Observations of the LAVM/RV and crews performing recovery scenarios were made at Camp Pendleton, California, during the week of 30 January to 3 February 1984. Observations of recovery tasks included:

Scenarios:

1. Towing of LAV vehicles.
    a. up slopes
    b. across slopes
    c. across rough terrain
    d. across wet terrain

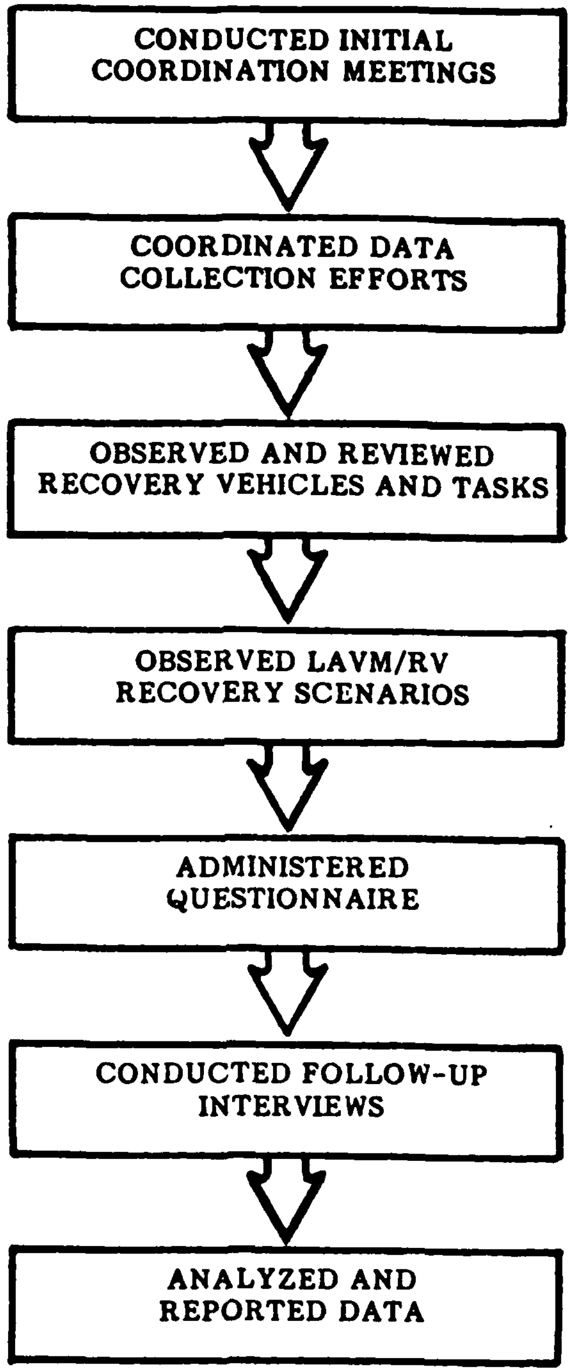

Figure 2. Sequence of the LAVM/RV human factors assessment activities.

2. Recovery of mired vehicles.
   a. axle depth
   b. axle depth and on a slope
   c. sponson depth at rear of vehicle

3. Self-recovery, mired to axle depth.

Associated tasks and conditions:

1. Fuel transfer,
2. Loading and unloading the LAVM/RV,
3. Vehicle maintenance,
4. Cross-country and highway travel,
5. MOPP conditions.

Observations were made by a human factors engineering specialist having participated in five previous operational tests. Test Operations Procedure 1-2-610 (November 1983) was used to guide the on-site observations. Observations of the crews were made from outside of the LAVM/RVs while the vehicles were operating. Inspections of the crew stations occurred while the LAVM/RVs were stationary. Crewmen performed scenarios three or four times during the human engineering assessment. Observations were used to extend the human factors engineering specialist's understanding of the concerns identified from the analysis of the structured interviews and of the questionnaire.

Some of the scenarios scheduled in the OT II test plan were not possible to observe due to changes in the Army test plan, the schedule, and the budget limitations of the human factors assessment. Moreover, due to an unsafe condition within the vehicles (to be described later), it was impossible to obtain instrumented measures of noise, temperature, or humidity. After observations were made, structured interviews were conducted following the completion of the scenarios. Crew members were interviewed individually.

Questionnaires were administered at Camp Pendleton during the week of 6-10 February 1984. The questionnaires were administered to five crew members at a time in a classroom. A human factors specialist was present throughout the session to explain instructions and to answer any questions from respondents.

Followup interviews were conducted after a preliminary analysis of the questionnaire data was performed. The interviews were used to:

1. Pursue information leads suggested by the data,
2. Assure proper interpretation of the questionnaire data,
3. Assure that no issues of concern were omitted.

Data were analyzed and reported upon completion of the site visits. The purpose of the assessment was to find human factors deficiencies; thus, only deficiencies are reported. Many facets of the LAVM/RV and its operation involve no deficiencies and can be reviewed in the raw data summarized in Appendix A. A deficiency was reported if:

1. Questionnaire items received a mean (M) rating of 3.5 or less (rating ranges; very inadequate 1 to 1.4; inadequate, 1.6 to 2.5; borderline, 2.6 to 3.5; adequate, 3.6 to 4.5; very adequate, 4.6 to 5.0; and in a like fashion, ratings for very difficult to very easy).

2. Crewman reported human factors or safety concerns during the structured interviews.

RESULTS

Human factors engineering deficiencies were found for 11 major areas of investigation. Table 3 lists summarized questionnaire results receiving ratings from "borderline" to "very inadequate," while Table 4 lists summarized hazard identification results. The summary tables are followed by descriptions of the human factors deficiencies identified during the assessment. Recommendations of ways to reduce the impact of the human factors deficiencies are included.

Ingress and Egress

Hatches and doors. Sixty percent of the crew reported safety hazards involving obstructed hatches and rear doors. Figure 3 shows the crane blocking the rigger's hatch while Figure 4 shows the towing pintle blocking the rear doors. Both hazards prevented the rear crew positions from being occupied during testing when the vehicles operated "buttoned-up." The safety hazard also prevented the human factors specialist from obtaining instrumented measures of noise, ventilation and lighting under these conditions. Unless corrected, the crews cannot rapidly enter or exit the vehicle. Moreover, the rigger cannot button-up without operating the crane. The hazards become especially dangerous if the vehicle is being attacked or if evacuation is necessary.

Additionally, both drivers reported that the M60 machinegun and mount, when traversed over the driver's hatch, blocks the hatch (see Figure 5). The gun and mount not only interfere with entering or exiting the driver's station but they also may endanger the driver's life when the gun is firing.

Design changes might include pivoting hatches for the rigger and driver, relocating the rigger's hatch farther to the right of crane, lowering the tow pintle below the rear doors, raising or changing the position of machinegun mount.

Hatch and door design for evacuation. The crew reported that the design of the hatches and rear doors were inadequate and at best, borderline for evacuating wounded (mean ratings 2.1 and 3.3, respectively). Hatches may be too narrow for personnel to pull the wounded out of the inside compartments (hatch length approximately 28 in (71 cm)). The additional bumping and handling required to pull victims through the narrow hatches may cause additional damage to the wounds. The rear doors are large enough to be used to evacuate the wounded (door height and width approximately 41 x 55 in (104 x 140 cm)), however, passages to the rear doors are obstructed by structures and stowed equipment. Design changes might include increasing the diameter of the hatch openings, adding padding around openings, and removing obstructions in the vehicle passageways.

Table 3

Summarized Questionnaire Results

Questionnaire Item No.	Summarized Question Topic	(Mean Rating) and Scale Descriptor		Implications for Crew and Equipment
1.	Comfort of mechanics seat.	M = 2.7	Borderline	Discomfort and/or back injury likely especially during prolonged travel.
2.	Protection from vibration in mechanic's seat.	M = 3.3	Borderline	Back injury likely (especially during prolonged travel.
3.	Seat comfort for sleeping:			
	Driver's seat	M = 2.0	Inadequate	Immediate and preferred shelter for sleeping in the field is unavailable.
	Commander's seat	M = 2.0	Inadequate	
	Rigger's seat	M = 2.3	Inadequate	
	Mechanic's seat	M = 3.2	Borderline	
4.	Vertical seat adjustment: Rigger's seat	M = 3.3	Borderline	May be time consuming to position. Seat likely to be unused.
5.	Seat adjustment for open hatch position: Rigger's seat	M = 3.1	Borderline	Seat likely to be used.
8.	Visual coverage from periscopes: Driver's	M = 3.0	Borderline	Personnel or objects to sides or rear of machine are likely to be undetected.
9.	Periscopes used during darkness: Driver's	M = 2.5	Borderline	Poor visibility during low light conditions.
10.	Periscope position to avoid blindspots: Driver's	M = 2.8	Borderline	Personnel or objects to the sides or rear of machine are likely to be undetected.

Table 3 (cont'd)

Questionnaire Item No.	Summarized Question Topic	(Mean Rating) and Scale Descriptor		Implications for Crew and Equipment
11.	Locking hatches half open	M = 3.0	Borderline	Hatches, often in this position, cannot be locked open and are likely to slam shut.
14.	Hatch design for evacuating wounded.	M = 2.1	Inadequate	May cause additional injury to wounded. May increase time needed to evacuate during emergency.
15.	Rear door design for evacuating wounded.	M = 3.3	Borderline	May cause additional injury to wounded.
16.	Easy entry or exit from hatches:			Blocked by crane.
	Rigger's hatch	M = 2.3	Inadequate	Time consuming to clear passage. May trap crew members.
17.	Hatch seal when locked:			NBC contaminates and water may enter vehicle.
	Rigger's hatch	M = 2.4	Inadequate	
18.	Ventilation and comfort:			Crew exposure to extreme hot temperatures, dust, fumes, and vapors.
	Hatches open, vehicle moving	M = 3.3	Borderline	
	Hatches open, vehicle standing	M = 3.2	Borderline	
	Hatched closed, vehicle moving	M = 2.3	Inadequate	
	Hatches closed, vehicle standing	M = 2.2	Inadequate	
	Hatches open, vehicle moving, hot weather	M = 3.1	Borderline	
	Hatches open, vehicle standing, hot weather	M = 2.9	Borderline	
	Hatches closed, vehicle moving, hot weather	M = 2.6	Borderline	
	Hatches closed, vehicle standing, hot weather	M = 1.9	Borderline	
	Hatches closed, vehicle standing, hot weather	M = 3.3	Inadequate	

Table 3 (cont'd)

Questionnaire Item No.	Summarized Question Topic	(Mean Rating) and	Scale Descriptor	Implications for Crew and Equipment
19.	Heating system comfort with hatches open, vehicle moving.	M = 3.3	Borderline	Crew exposure to extreme cold temperatures.
20.	Fume removal by ventilation system:			Crew exposure to fumes and vapors should they occur.
	Hatches closed, vehicle moving	M = 3.2	Borderline	
23.	Interior blue lighting at crew stations:			Personnel unable to see well enough to perform tasks. Increased time to perform tasks. Errors likely.
	Rigger's station	M = 3.1	Borderline	
	Bilge pump	M = 3.0	Borderline	
	Crane onboard controls	M = 2.2	Inadequate	
	Fuel transfer pump	M = 3.0	Borderline	
	Winch	M = 3.1	Borderline	
	Tool storage space	M = 3.0	Borderline	
24.	Noise protection:			Hearing damage possible. Needs further investigation. Noise interference with verbal and intercom communication likely.
	Hatches closed, engine warmup	M = 3.2	Borderline	
	Hatches closed, traveling 30 mph or greater	M = 3.1	Borderline	
30.	Using workbench.	M = 3.0	Borderline	Workbench likely to be unused.
31.	Workbench features:			Workbench likely to be unused. Crew discomfort may reduce time spent at workbench. Discomfort make make errors likely.
	Space for work	M = 2.7	Borderline	
	Armroom when seated	M = 3.3	Borderline	
	Legroom when seated	M = 2.1	Inadequate	
	Seating	M = 2.5	Inadequate	
	Ventilation	M = 3.4	Borderline	
	Storage for tools	M = 3.3	Borderline	
	Overall comfort	M = 2.5	Inadequate	

Table 3 (cont'd)

Questionnaire Item No.	Summarized Question Topic	(Mean Rating) and Scale Descriptor		Implications for Crew and Equipment
38.	Wearing NBC MOPP IV gear while working:			Heat exhaustion possible. May increase time to perform tasks. Clothing likely to interfere with verbal and intercom communications.
	Using rigging and towing equipment	M = 3.2	Borderline	
	Removing and replacing power packs	M = 3.2	Borderline	
	Conversing with other crew members	M = 3.3	Borderline	
41.	Donning NBC MOPP IV gear at crew station:			Crew exposure to NBC contaminants if attacked with NBC weapons. Time and attention is diverted from other vehicle tasks. Survivability decreases.
	Driver's station	M = 3.1	Borderline	
	Commander's station	M = 2.9	Borderline	
	Rigger's station	M = 2.3	Inadequate	
	Mechanic's station	M = 2.8	Borderline	
43.	Size of storage space:			Equipment likely to be stacked in passageway. Time to perform tasks may increase. Evacuation of vehilce may be hindered.
	Ammo	M = 3.0	Borderline	
	Common tools	M = 3.2	Borderline	
	Special tools	M = 3.2	Borderline	
	NBC gear	M = 3.1	Borderline	
	Repair parts	M = 3.1	Borderline	
	Personal gear	M = 3.2	Borderline	
	TMDE diagnostic equipment	M = 3.3	Borderline	
44.	Storage location:			May increase time required to obtain tools. Tools may not be returned to proper storage location.
	Common tools	M = 3.2	Borderline	
	Special tools	M = 3.2	Borderline	
	NBC gear	M = 3.0	Borderline	
	Repair parts	M = 3.2	Borderline	
	Personal gear	M = 3.2	Borderline	
	TMDE diagnostic equipment	M = 3.3	Borderline	

Table 3 (cont'd)

Questionnaire Item No.	Summarized Question Topic	(Mean Rating) and Scale Descriptor		Implications for Crew and Equipment
45.	Easy access to storage:			May increase time required to obtain equipment.
	Repair parts	M = 3.3	Borderline	
	Personal gear	M = 3.3	Borderline	
46.	Protection of equipment provided by storage:			Possible equipment damage. Possible equipment shortage when in field.
	Ammo	M = 3.0	Borderline	
	Common tools	M = 3.3	Borderline	
	Special tools	M = 3.1	Borderline	
	NBC gear	M = 3.3	Borderline	
	Repair parts	M = 3.1	Borderline	
	Personal gear	M = 3.4	Borderline	
	TMDE diagnostic equipment	M = 3.2	Borderline	
47.	Loops/rails used for storage:			Loops and rails likely to be unused. Use may result in equipment damage.
	Exterior	M = 3.3	Borderline	
	Interior	M = 3.0	Borderline	
48.	Grasping (holding) features of:			Injury from lifting likely. Dropping of equipment likely. May increase time to transport.
	APU/welder	M = 3.3	Borderline	
	Tool boxes	M = 3.3	Borderline	
49.	Portability features of:			Dropping of equipment likely. May increase time to transport.
	Special tools	M = 3.3	Borderline	
	Diagnostic equipment	M = 3.3	Borderline	
	APU/welder	M = 3.3	Borderline	
50.	Use of equipment as planned:			Hoses likely to be unused. May cause mission failure.
	Fuel transfer hoses	M = 3.3	Borderline	

Table 3 (cont'd)

Questionnaire Item No.	Summarized Question Topic	(Mean Rating) and Scale Descriptor		Implications for Crew and Equipment
51.	Supply of repair parts.	M = 3.3	Borderline	May increase time to perform task. Equipment may remain unrepaired.
56.	Completeness of tool listing.	M = 3.1	Borderline	Vehicle may not be properly supplied.
61.	Easy removal of power pack inside panels.	M = 3.4	Borderline	Task may not be performed. May increase time to complete service.
63.	Easy removal of transfer case dog house.	M = 3.4	Borderline	Task may not be performed. May increase time to complete service.
64.	Easy service of transfer case.	M = 3.1	Borderline	Task may not be performed. May increase time to complete service.
67.	Easy use of crane base mounted controls.	M = 3.3	Borderline	May increase time to position crane. Errors likely.

Table 4

Summarized Hazard Identification Results

Questionnaire Item No.	Equipment Involved with Hazard	No. of Crew Members Reporting Hazard	Summarized Description of Hazard	Implications for Crew and Equipment
1.	Crane	3	Blocks rigger's hatch.	Hatch cannot be opened or closed in emergencies.
			Cannot see crane from onboard controls.	Crane may strike equipment or personnel.
				May require excessive time to operate.
2.	Winch	4	Cannot operate with rear doors closed.	Limited protection from cable snap.
				Limited protection if used during threat of combat.
			Spool free spools too rapidly. No spool brake.	May injure personnel if using hands as brake.
			Spool is too slow.	Cable loosens and may result in cable damage during spool in.
				Combat risk.
3.	Winch controls	8	Control wire is too short (approx. 20 ft, need 75 ft).	Rigger is in cable snap danger area.

Table 4 (cont'd)

Questionnaire Item No.	Equipment Involved with Hazard	No. of Crew Members Reporting Hazard	Summarized Description of Hazard	Implications for Crew and Equipment
			Rigger must frequently view wrapping of cable.	Rigger walks into close proximity of cable and into cable snap danger area.
4.	Crane remote controls	2	Control wire is too short.	May be difficult for an operator to be at a safe distance from loaded crane.
6.	APU/welder, generator	6	Heavy weight of unit (approx. 375 lbs).	Lifting injuries likely.
			Stored on rack next to wall.	Difficult and time consuming to stow APU onboard.
10.	Fuel transfer hoses	7	LAVM/RV fuel tank to fuel pump hose too short.	Fuel spillage likely inside LAVM/RV; fire and fume danger.
			Fuel pump to supported vehicle hose too short.	Vehicles involved in transfer may be dangerously close when on rough terrain.
11.	M60 machinegun mount	2	Gun mount blocks opening and closing of driver's hatch.	Driver's hatch may be blocked.
				Driver's head may hit gun mount.
				Hatch may interfere with aiming of gun.

Table 4 (cont'd)

Questionnaire Item No.	Equipment Involved with Hazard	No. of Crew Members Reporting Hazard	Summarized Description of Hazard	Implications for Crew and Equipment
14.	Driver's hatch	2	Driver cannot see instruments when at periscope height or higher. Warning lights (BITE panel) completely blocked.	May lead to vehicle damage or failure.
15.	Commander's hatch	1	Smoke grenade fire trigger is too close to hatch.	Accidental firing; may injure personnel on surface of deck.
16.	Rigger's hatch	6	Blocked by crane.	Hatch cannot be opened or closed in an emergency.
				Hatch may strike personnel if struck by crane.
17.	Rear doors	6	Blocked by towing pintle.	Cannot open or close doors during towing.
			Door cannot open if rear of vehicle is in deep mire.	Cannot open doors when in deep mire.
				Equipment stored in interior is difficult to obtain.
21.	Tow bar	4	Too short to view by rigger or driver of supported vehicle.	Cannot see tow bar should stress cause damage to it.
			Heavy tow bar (approx. 200 lbs) is stored on upper deck.	Lifting injuries likely.
				Dropping may result in damage to equipment or injury.

Table 4 (cont'd)

Questionnaire Item No.	Equipment Involved with Hazard	No. of Crew Members Reporting Hazard	Summarized Description of Hazard	Implications for Crew and Equipment
23.	Crew seats	4	Too little legroom.	Leg injury likely during travel over rough terrain.
24.	Tool and equipment storage	2	Tool boxes and other equipment unsecured.	Injury by flying or sliding objects likely.
28.	Top walking surfaces	1	No friction producing surface on power pack grills.	Slip and fall injury likely when wet or oily.
29.	Steps and handholds	2	No friction producing or gripping teeth on footholds.	Slip and fall injury likely when wet, muddy, icy or oily.
30.	Storage compartments	4	Most equipment unsecured.	Injury or equipment damage likely by sliding or flying objects.
None	Driver's seat	Noticed by on-site human factors engineers; confirmed by two vehicle commanders.	Commander's foot can be positioned beneath descending driver's seat.	Injury to commander's foot likely.
None	Amphibious propellers	AS ABOVE	Propeller blades unguarded.	Injury to personnel in close quarters such as on naval vessels likely.

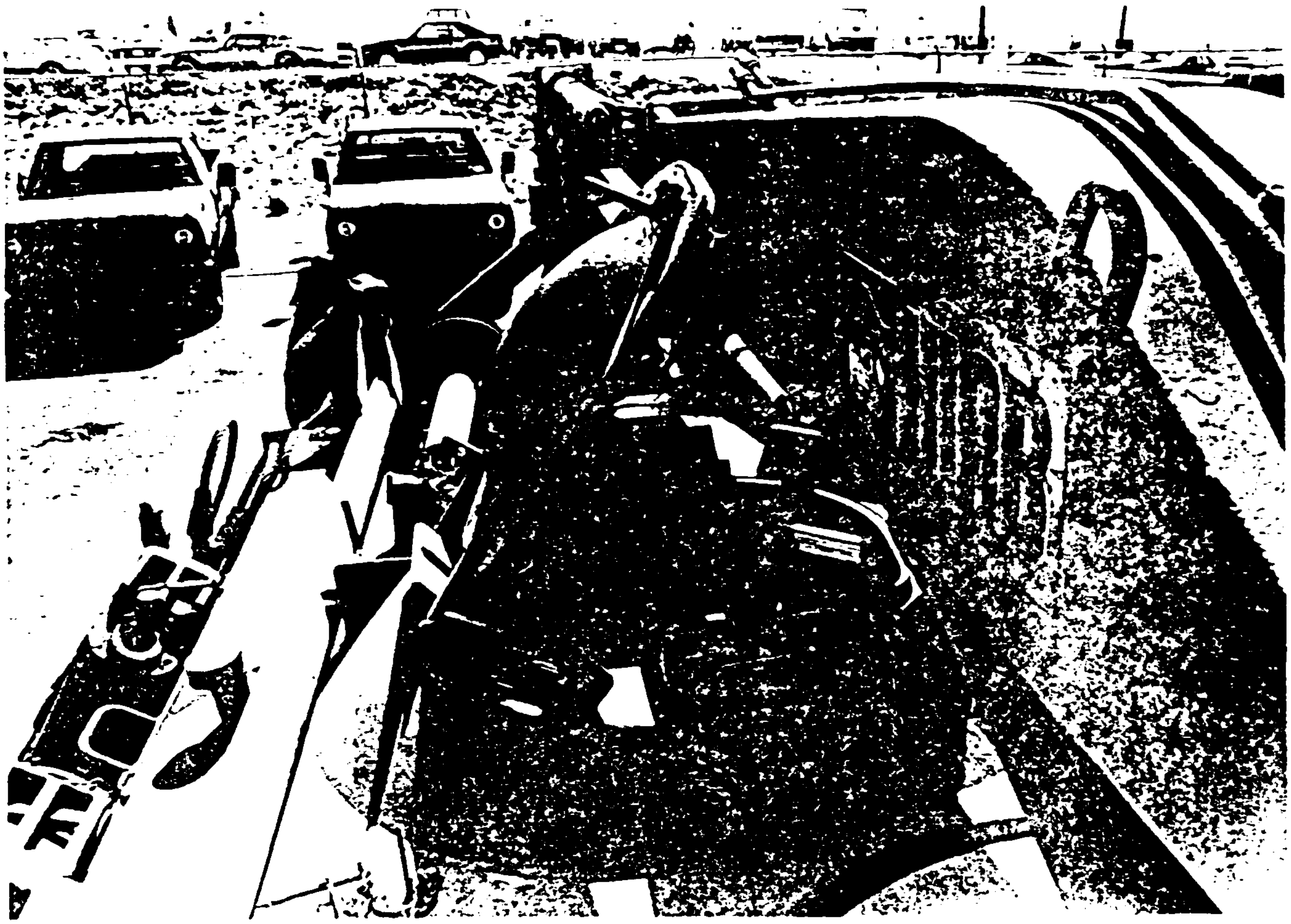

Figure 3. The crane blocks the opening and closing of the rigger's hatch.

Figure 4. The tow pintle blocks the opening and closing of the rear doors.

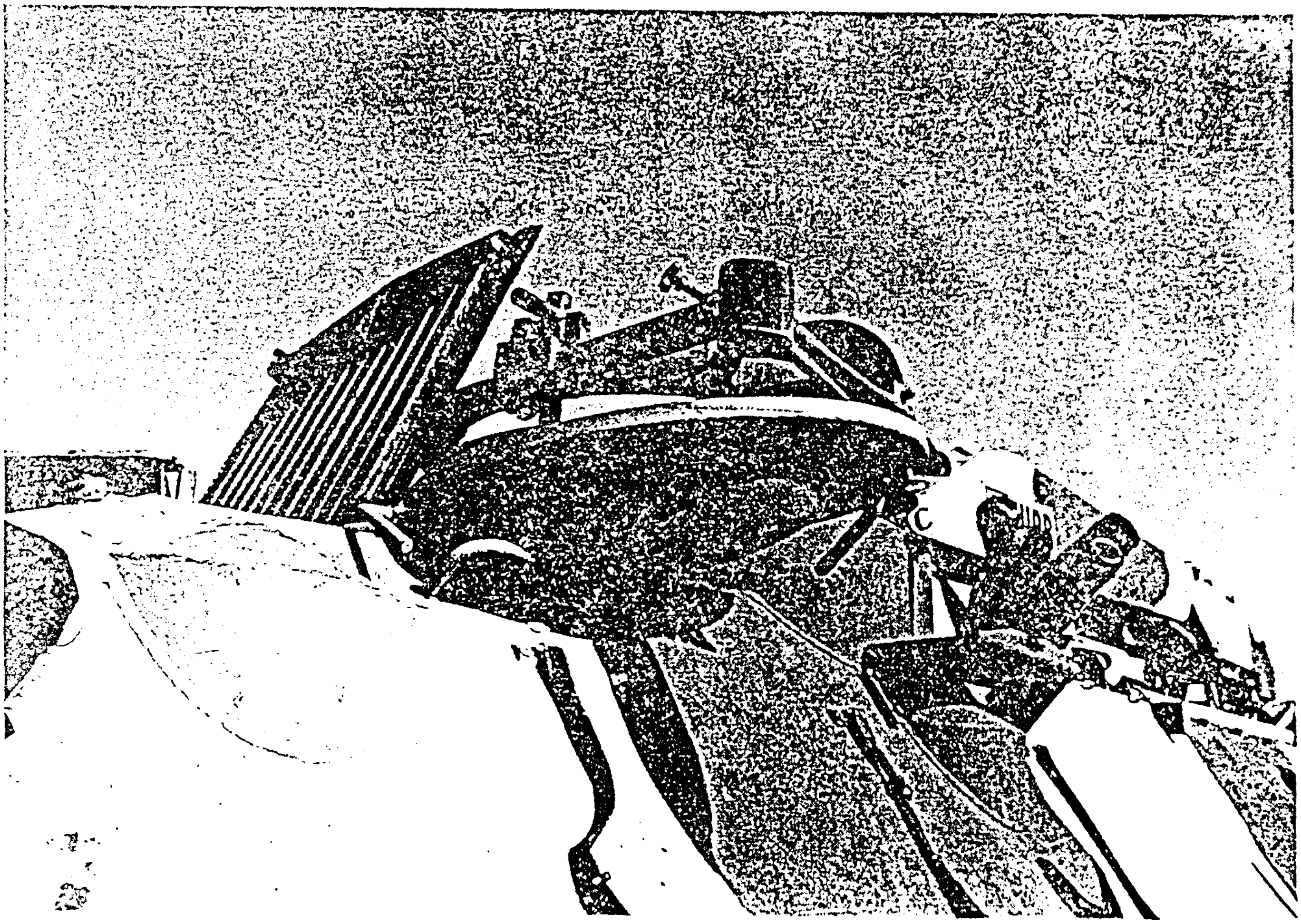

Figure 5. The M60 gun mount (above the open hatch) blocks the opening or closing of the driver's hatch.

Steps, handholds, and walkways. Thirty percent of the crew reported that steps, handholds, and top walking surfaces were hazardously slippery. Figure 6 shows the design and location of steps/handholds while Figure 7 shows the power pack grills. Steps and handholds do not have a nonslip surface and are extremely slippery when wet or oily. Design changes should include adding nonslip surfaces to these vehicle features. Steps and handholds might have a "knobby" upper edge that prevents boot soles caked with mud from slipping, yet does not cause pain to the hands. Steps should also be wide enough for both feet because crew members position themselves on the step to load and unload equipment.

Hatch seals. The crews rated the seals at the rigger's station as inadequate (mean rating, 2.4). Moreover, the drivers of both vehicles reported leaking seals at their stations. The hatch and door seals showed damages that may have been caused by collision with equipment. The driver's hatch seal appeared to have been damaged by lowering the hatch while the latch handle was in lock position, resulting in the handle striking the seal. Leaking seals may jeopardize crew safety especially during amphibious operations and NBC attack. Seals should be protected from collision with equipment. Design changes might include redesign of hatch latch handles. Caution labels might be positioned on doors and hatches. Warnings might be included in operator literature and training.

Control Stations

Driving controls. Both drivers interviewed reported several control/display location problems. Figure 8 shows the gear shift and transfer case lock levers. These control levels are identical and located to the driver's left side. The gear shift lever is on the left and is the farthest lever from the driver. It is also the most frequently used lever. The lever handles are approximately three inches apart. Human factors deficiencies include:

1. The drivers have difficulty determining which lever is in their hand by touch alone.

2. The drivers have difficulty determining which lever is in their hand by position alone. The levers are close together and one lever is slightly higher than the other. The driver's seat height has a wide range of adjustability in height (10.5 in (27 cm)). Thus, the lever heights relative to the driver's seated height change and are not reliable cues.

3. The less frequently used transfer case lock lever may be bumped by the driver's arm or hand when he tries to use the gear shift lever.

4. Accidental activation of the transfer case lever is likely to result in damage to the vehicle's drive train.

Design changes might include separating and relocating the control levers. In addition, position the gear shift lever closer to the driver than the transfer case lever. Change the knob configuration of the transfer case lever. A "T" handle shape might be a helpful shape code that distinguishes the transfer case lever and initializes its function.

The driver's turn signal lever is located beneath the steering wheel. When the driver's seat is raised to a height allowing him to use the periscopes, his left knee strikes the signal lever housing resulting in pain. The lever housing location should be changed.

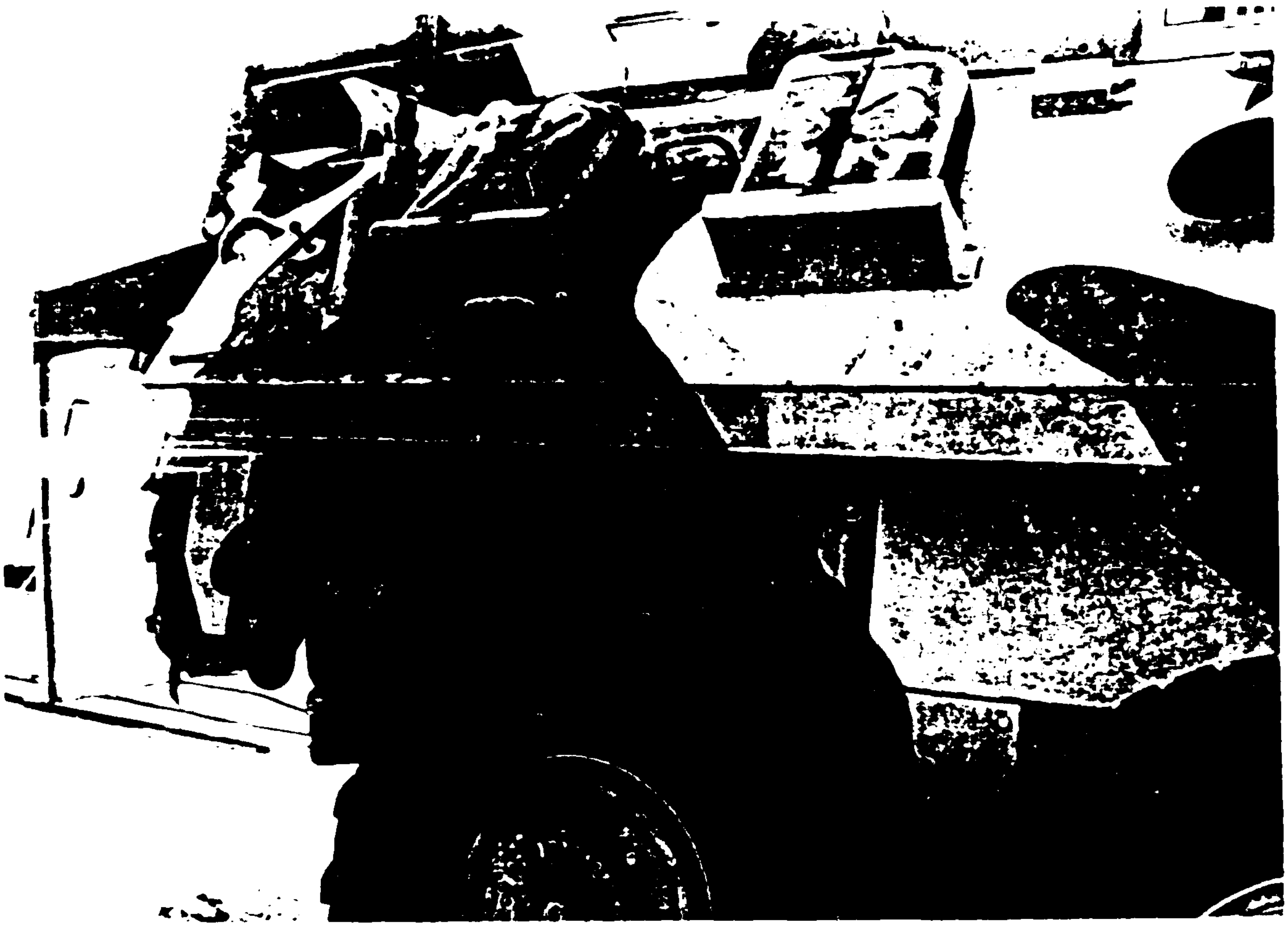

Figure 6. Steps and handholds are without a nonslip surface and are blocked by equipment.

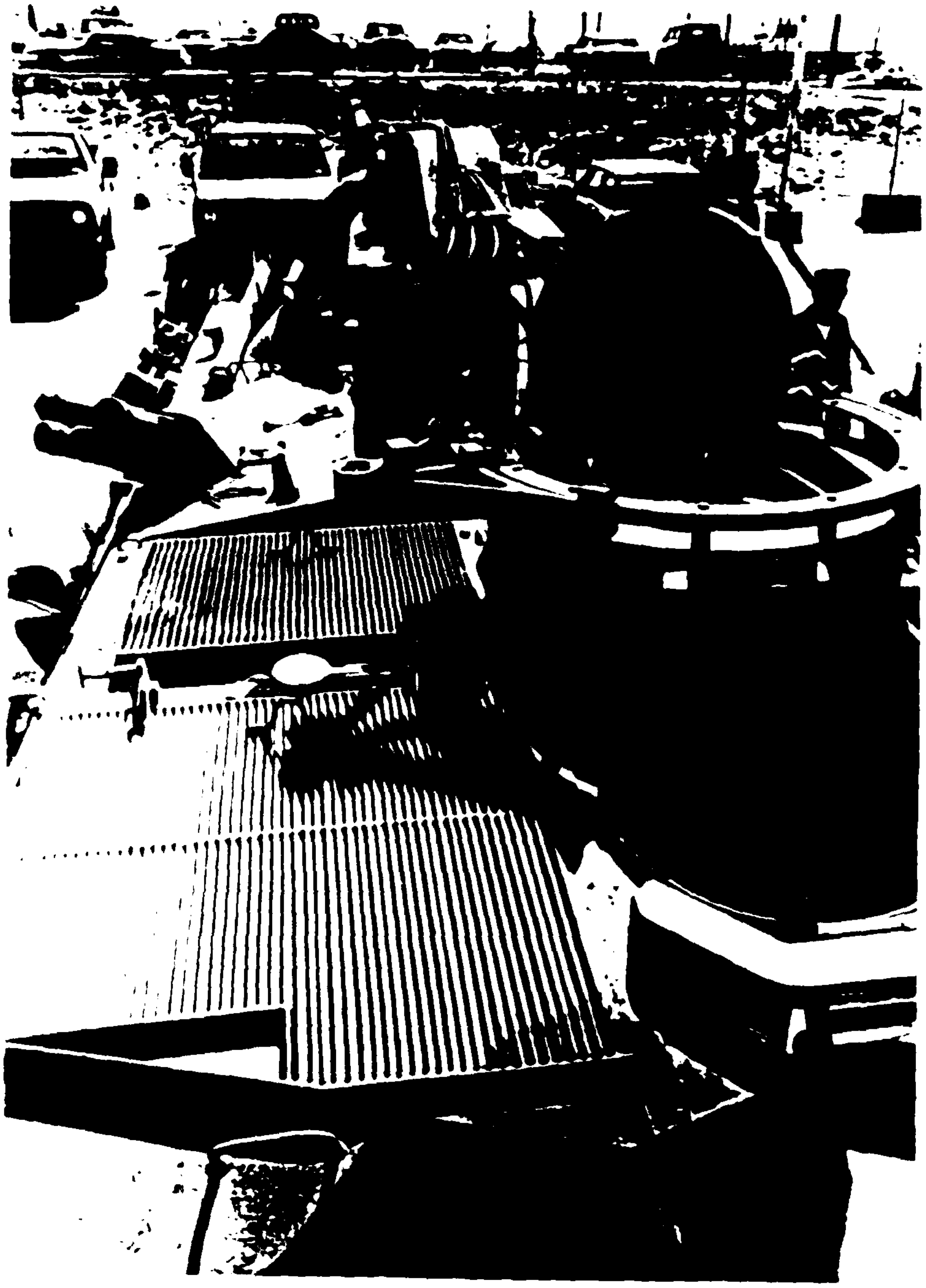

Figure 7. Power pack grills are without a nonslip surface.

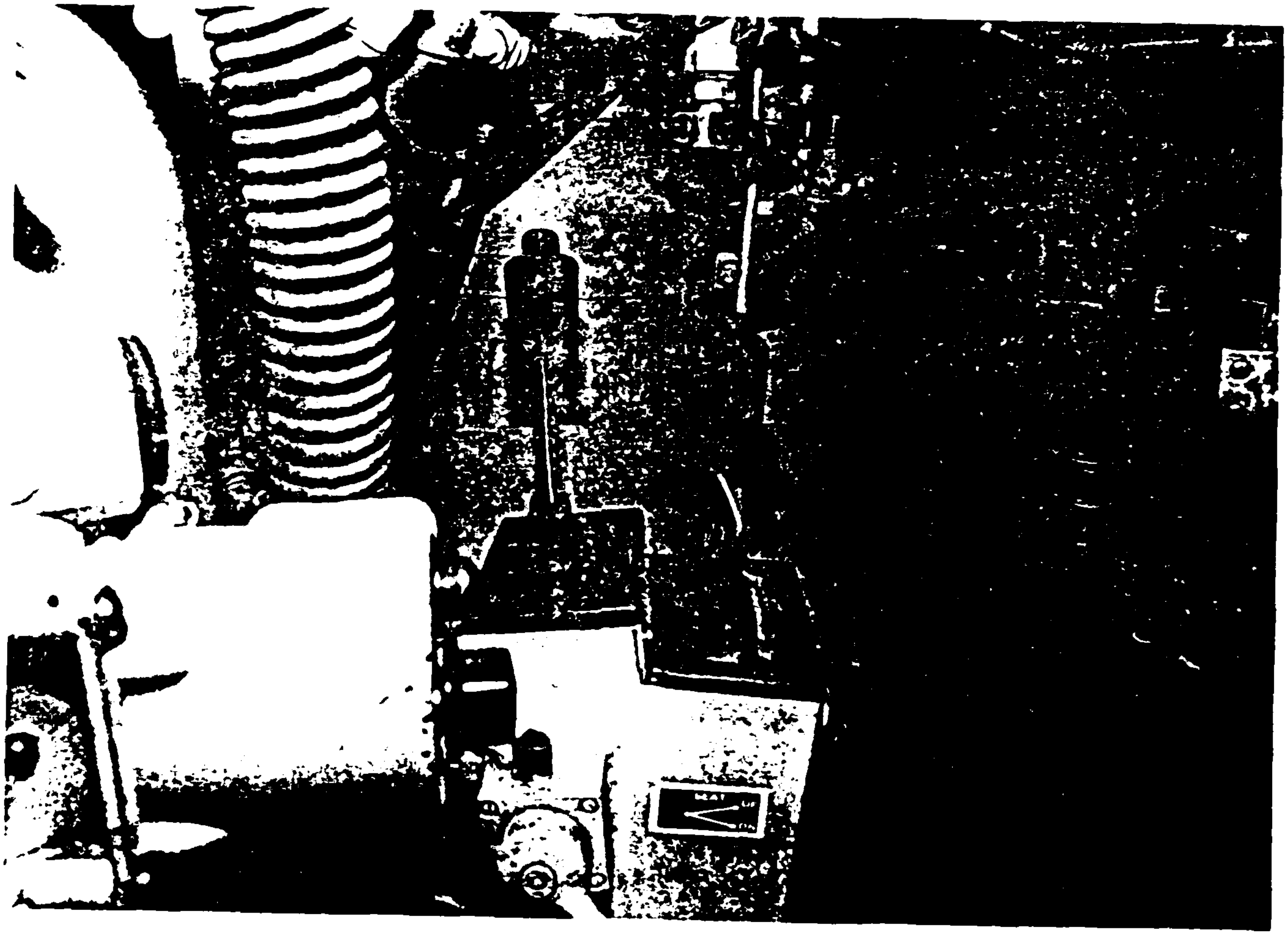

Figure 8. The gear shift (left) and transfer case lock (right) are too similar and may be accidentally activated.

There is no clearance space between the driver's knee when he raises his seat to open hatch height and the housing regardless of the driver's body size. Thus, it is unlikely that adding padding to the underside of the housing would improve the situation.

The gauges and various control switches are located behind the driver. Figure 9 shows the location of the gauge display panel behind the driver's left shoulder. The location of the panel was probably chosen due to the limited space available in front of the driver and to allow the commander a view of the panel. Due to the obvious space limitations, the panel location may be the only suitable position for most of the panel's gauges and switches, however, both drivers reported that they need a better view of the engine temperature and oil pressure gauges. The gauges are presently located on the upper right corner of the panel, yet they are completely out of the driver's line of sight. It is recommended that these gauges be moved to a position in front of the driver. The importance of the gauges may increase should the LAVM/RV operate in hot climates where high engine temperatures must be carefully monitored and regulated.

Several test personnel reported that the driver's view of the Built-In Test Equipment (BITE) warning annunciator panel was partially blocked by the steering wheel or not visible when the driver has his seat raised for open hatch operation. The BITE panel sounds a highly audible ringing warning signal when any of the panel's warning lights are lighted. Thus, due to the limited space available for the panel, and due to the panel's easily detectable warning signal, it is not necessary for the operator to change the BITE panel location.

Both drivers reported the need for a "hot hydraulics" warning signal. A signal and gauge should be provided and may be especially important when the vehicle's hydraulic equipment is used in hot climates.

<u>On-board crane controls.</u> The crews rated the use of the on-board, base-mounted crane controls as borderline (mean rating, 3.3). Thirty percent of the crews felt that it was hazardous to use the on-board control because the crane cannot be viewed from the control station. Figure 10 shows the on-board control station and the symbols on the levers. The on-board controls will be used when the remote controls are inoperable, foul weather occurs, threat of combat occurs, or if a single, quick adjustment to the crane's stored position is necessary. The controls are located behind the commander's station and approximately seven inches above the vehicle floor. The controls have several human factors deficiencies, including:

1. The operator cannot view the crane responses to the control lever movements. The operator can see very little crane movement through the periscopes. Moreover, the operator's head height when handling the control levers is approximately 20 in (51 cm) below the open hatch level. Finally, the control levers are 119 in (302 cm) from the rear doors, making it impossible to view the crane's movement.

2. The control symbols are too small to be easily viewed. The symbols within the larger arrows are less than one-quarter inch in height. The symbols cannot be seen in low light or blue light conditions.

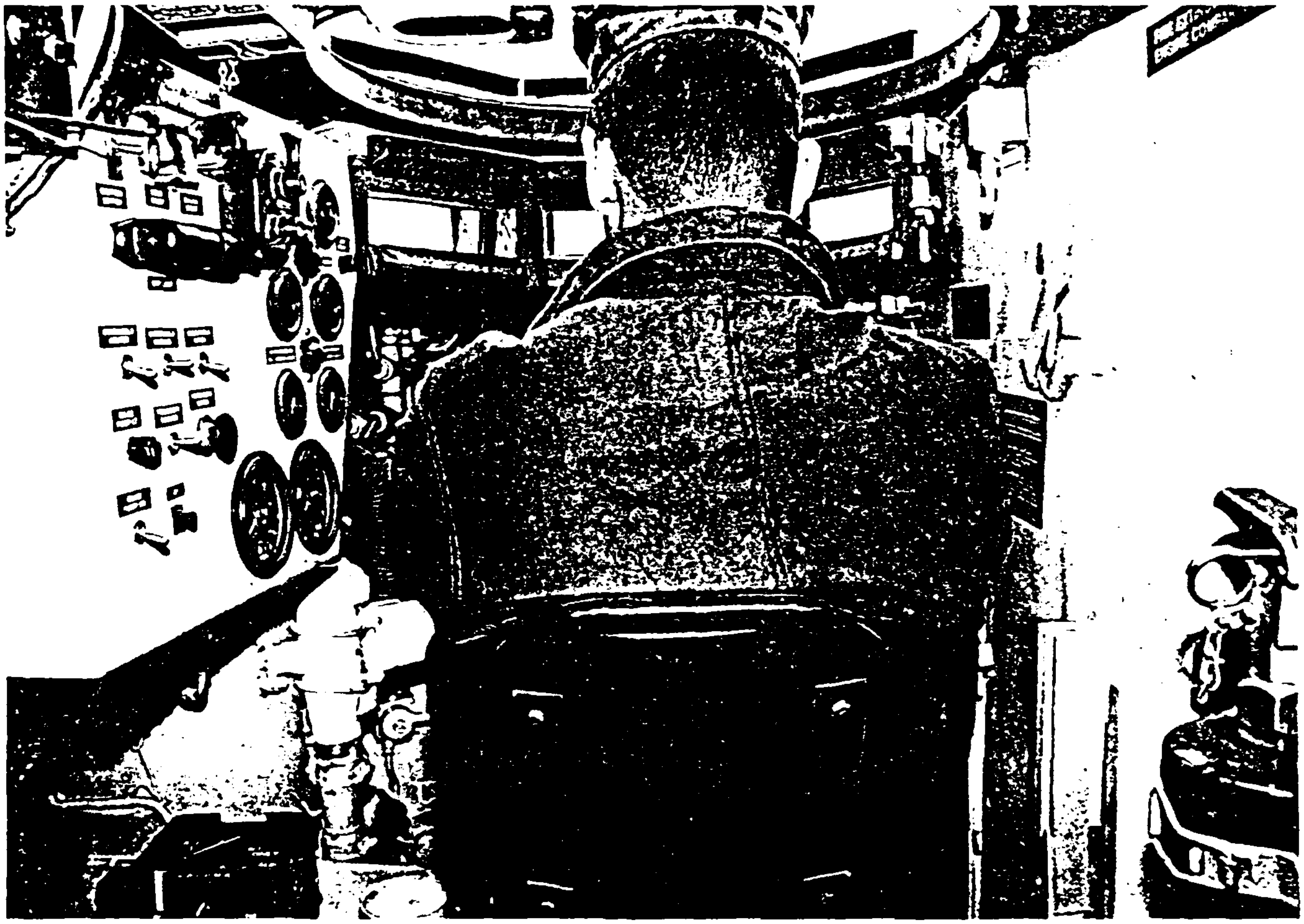

Figure 9. The gauge display panel (left) is difficult for the driver to see.

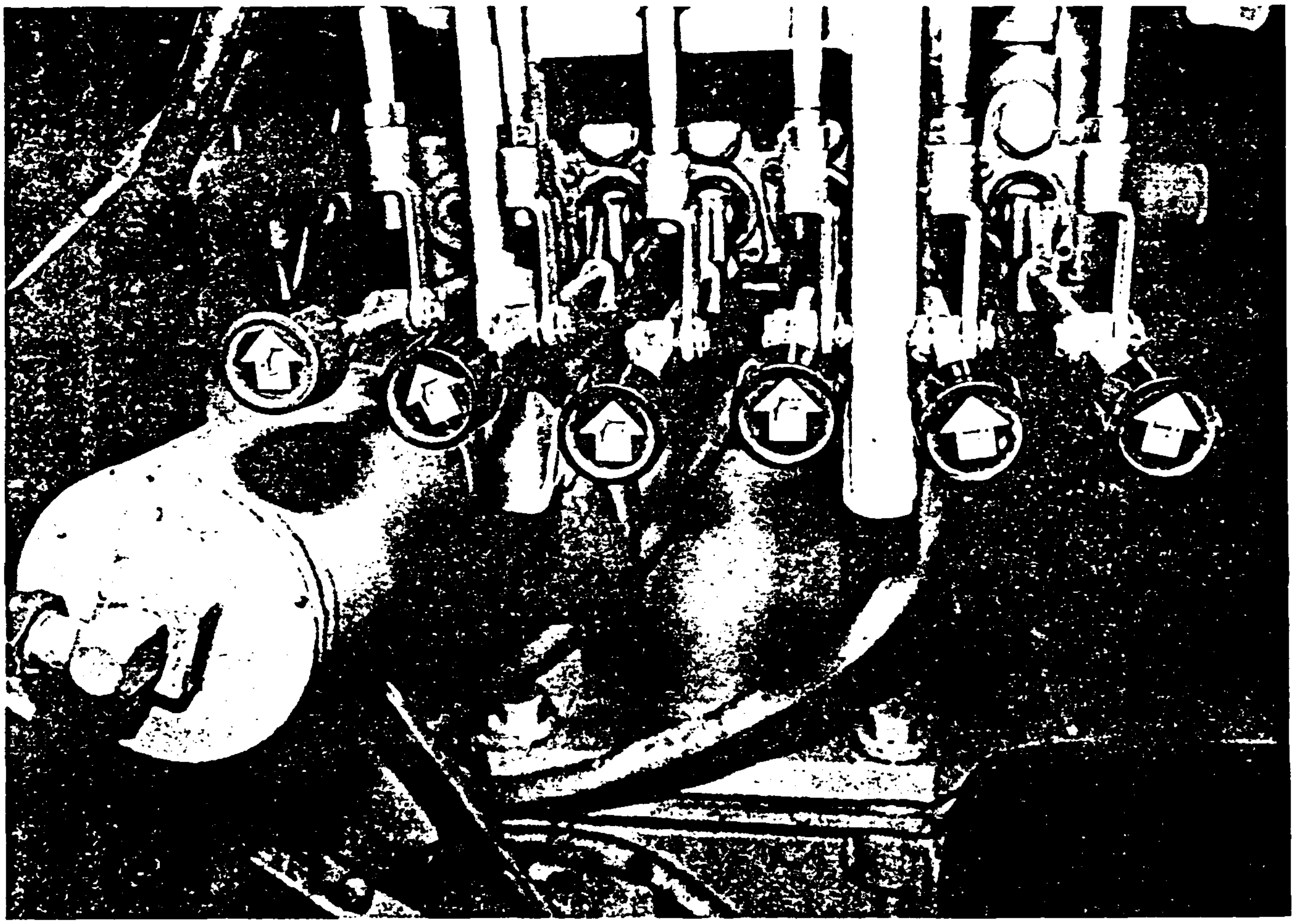

Figure 10. The on-board crane control lever symbols are difficult to view.

3. Control lever activation directions are the opposite of the machine response directions. Activating the inner and outer arm levers by moving them up causes the inner and outer crane arms to move down (the control levers are the second and third levers from the left in Figure 10).

4. The control knobs become unscrewed and often symbols point in incorrect directions.

Human factors deficiencies such as those listed above are likely to increase task completion time, errors, and may result in equipment damage or injury. All crane control levers should move in the same general direction as the crane functions they control. Design changes might include reversing (if possible) the position of the input and output hydraulic lines on the manifold for the inner and outer arm levers. Place larger control symbols directly in line with the control levers on the valve manifold housing (not shown in Figure 10). It may also be possible to turn the valve manifold over, appropriately switching the input/output lines, so that the control levers are closer to the commander's hatch and can be activated in the appropriate directions. This would also place the control symbols closer to the overhead light.

Winch controls. Eighty percent of the crews reported that it was hazardous to operate the winch controls on the 20 ft (6.1m) control wire. The rigger cannot position himself safely outside the cable snap danger area as specified by recovery vehicle Field Manual ST 17-20-22. The control wire would have to be 100 ft (34.5m) long (the length of the winch wire rope) and the rigger would have to work at this distance in order to be positioned safely. Since this distance is probably impractical, an alternative would be to winch through a rear door port so that the rear doors could be closed. A housing would also have to be provided for the winch. The rigger could then operate the winch from his station inside the vehicle.

One-hundred percent of the crews reported in the specific scenario interviews that it was difficult to stop the free spooling of the wire rope without a free-spool brake. One crew member injured his hand when he attempted to stop the spool from turning. The free spooling causes the wire rope to loosen on the drum which may cause damage to the wire rope during "spooling in." The wire rope also needs to be tightly wrapped on the drum to maximize winch capacity. It is recommended that a free spool brake be added to the winch.

Forty percent of the crews reported that the winch spools in too slowly, and therefore, represents a hazard during the threat of combat. The slow "spool in" rate combined with the crew having to adjust the wire rope alignment, due to its loosening during spooling out, resulted in a "spool in" rate of 10 feet per minute. Spooling in the entire 100 foot wire rope took 15 minutes. It is recommended that a two-speed "spool in" control be added to the winch controls that allows spool in at a faster rate for emergencies.

Eighty percent of the crews reported that the rigger must repeatedly approach the winch while spooling in to visually inspect for proper alignment of the wire rope (three to four inspections for 50 feet of wire rope). This places the rigger in extreme danger should the wire rope break. To avoid this hazard a self-aligning device (sometimes called a "line leveler") might be added to the winch.

Storage Space

Tool and accessory storage. Crews rated the size and location of storage and the protection of equipment in storage as borderline (average mean rating, 3.1, see questionnaire items 43 to 46). Figure 11 shows the equipment carried in internal vehicle storage locations. Figure 11, however, does not show any combat gear which is also stored inside the vehicle. Figure 12 shows the equipment as it is usually stored in the vehicle. Notice that stored equipment is blocking the passageways. Figure 13 shows two of the three secure storage spaces allocated for all the equipment shown in Figure 11. Secure storage consists of two equipment trays (measuring 26 x 7 x 7 in (66 x 18 x 18 cm)) and one tool box (measuring 19.50 x 13.25 x 10 in (50 x 34 x 25 cm)). The lack of secure storage locations results in the stacking of equipment in any available space. The crew also reported that they stored equipment in their seated legroom and carried equipment in their laps when the vehicle was combat loaded. The lack of secure storage results in several problems, including:

1. Blocked passage ways,
2. Shifting loads, especially when traveling on rough terrain,
3. Equipment damage,
4. Increased time to locate and unload equipment,
5. The potential for injury of personnel when they trip or bump stacked gear, or are struck by shifting equipment.

Design changes should include additional storage boxes and specific locations in which equipment can be secured by straps. Changes to the interior configuration of the vehicle may also be necessary and are discussed later. A complete listing of items requiring storage space can be obtained from the LAVM/RV accessory equipment specification list.

APU storage location. The crews rated the portability of the APU/welder/generator as inadequate (mean rating, 2.5). Moreover, 60 percent of the crews reported that handling the APU was hazardous. Figure 14 shows the crew attempting to load the APU onto the vehicle's storage rack; a procedure which took 15 minutes during each of three separate loading trials. The human factors deficiency results from a combination of the APU's weight (375 lb (170 kg)) and its storage location (APU handrail height to ground is 45 in (114 cm)). Moreover, loading the APU is difficult because its storage rack is alongside the rear wall of the vehicle and access to the rack from the left side is completely blocked by the left rear door. During the loading of the APU, only two to three crew members can position themselves to lift and align the APU to its storage rack (lifting weight per person is 187.5 to 125 lb (85.05 to 56.70 kg)). MIL-STD-1472C limits the weight to 50 lb (3 kg) for a height of 48 in (127 cm). This human factors deficiency is likely to result in:

1. Injury to the crew,
2. Equipment damage to the APU or storage rack,
3. Abandonment of the APU during an emergency.

Design changes might include repositioning the APU to allow more of the crew to participate in lifting the device. However, even if all five crew members lift the APU, the lifted weight per person is 75 lb (34 kg) and violates the MIL standard. A better solution might be to add a sliding carriage rack to the APU storage rack that slides out and locks in place beyond the rear door opening. It would then be possible to load the

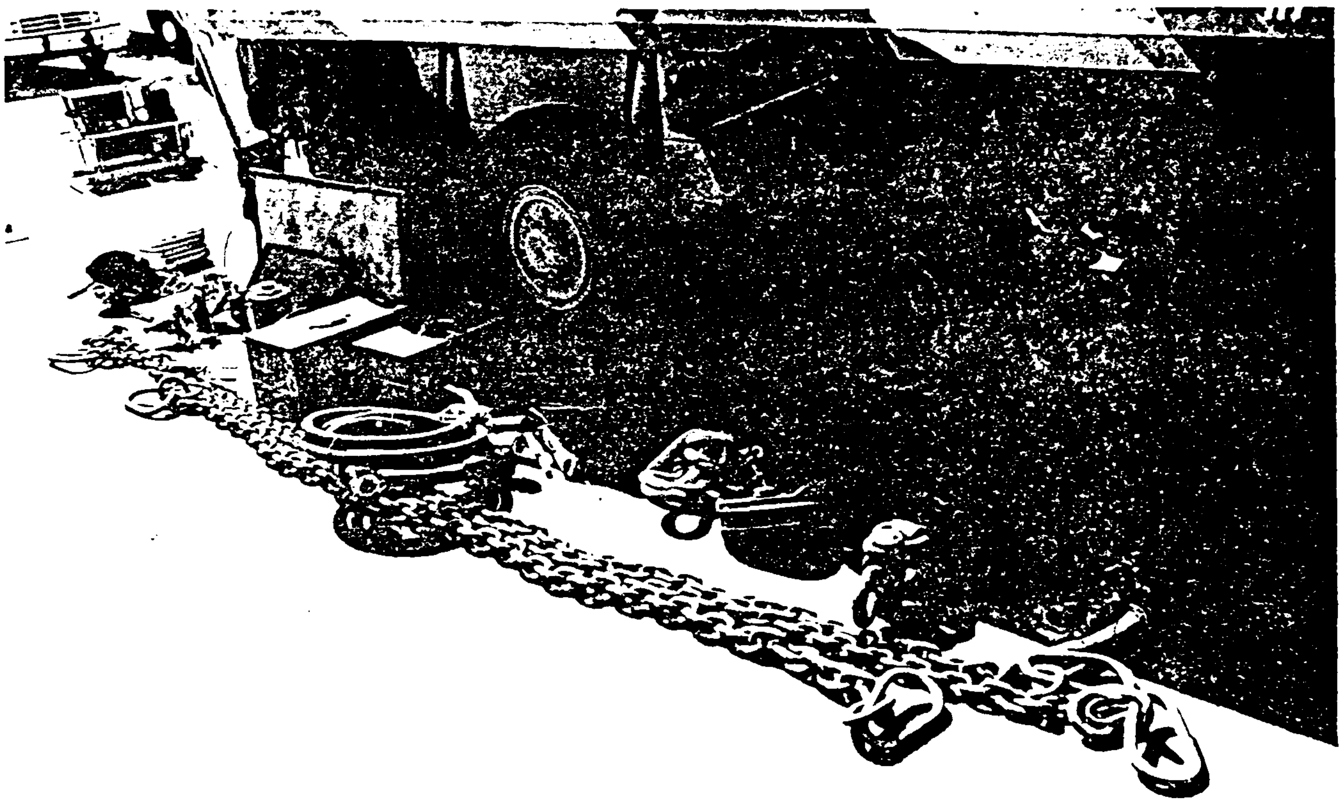

Figure 11. The equipment carried inside the vehicle. Additional combat gear is not shown.

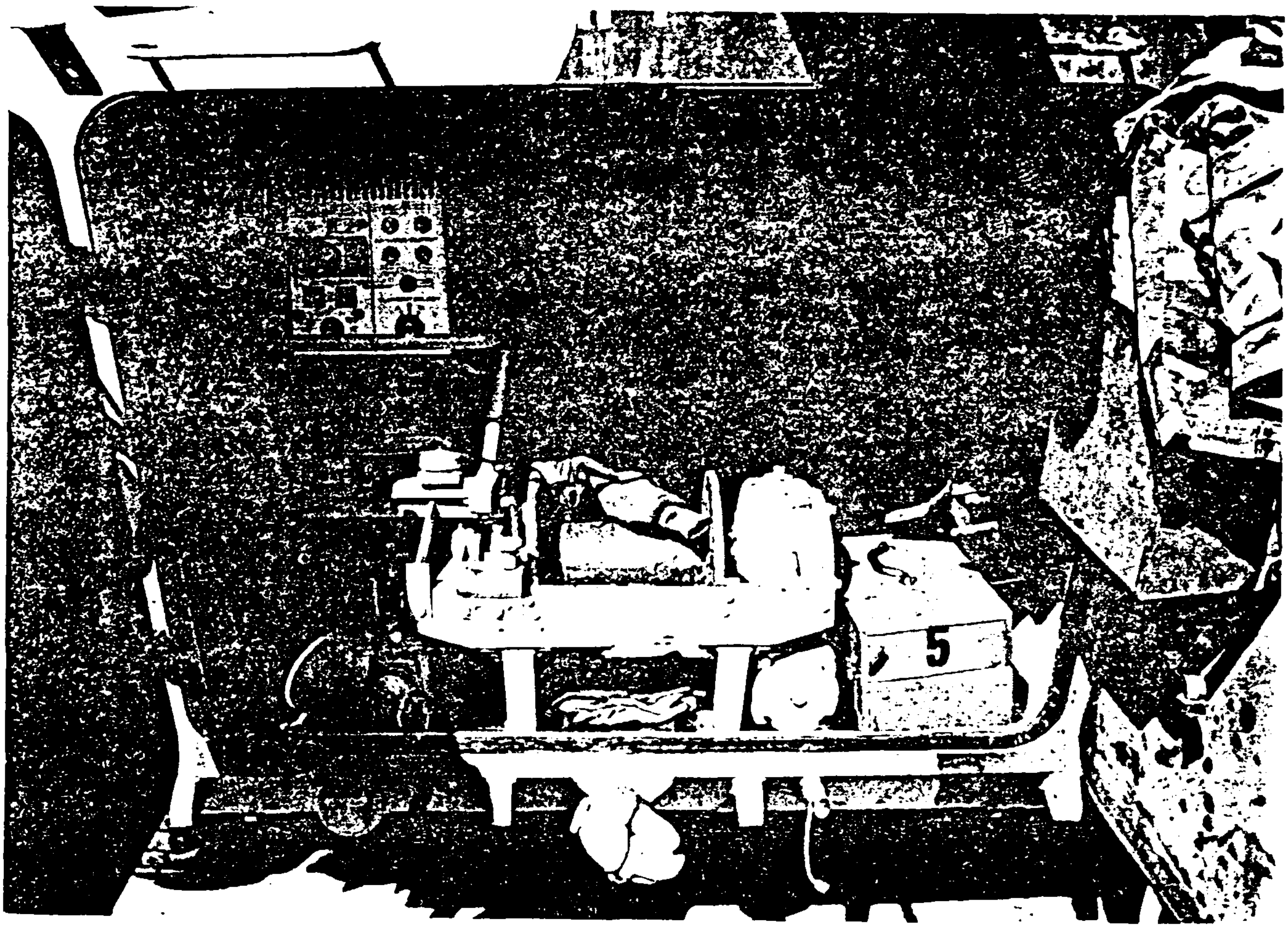

Figure 12. This is the way equipment is stored.

Figure 13. The secure storage locations.

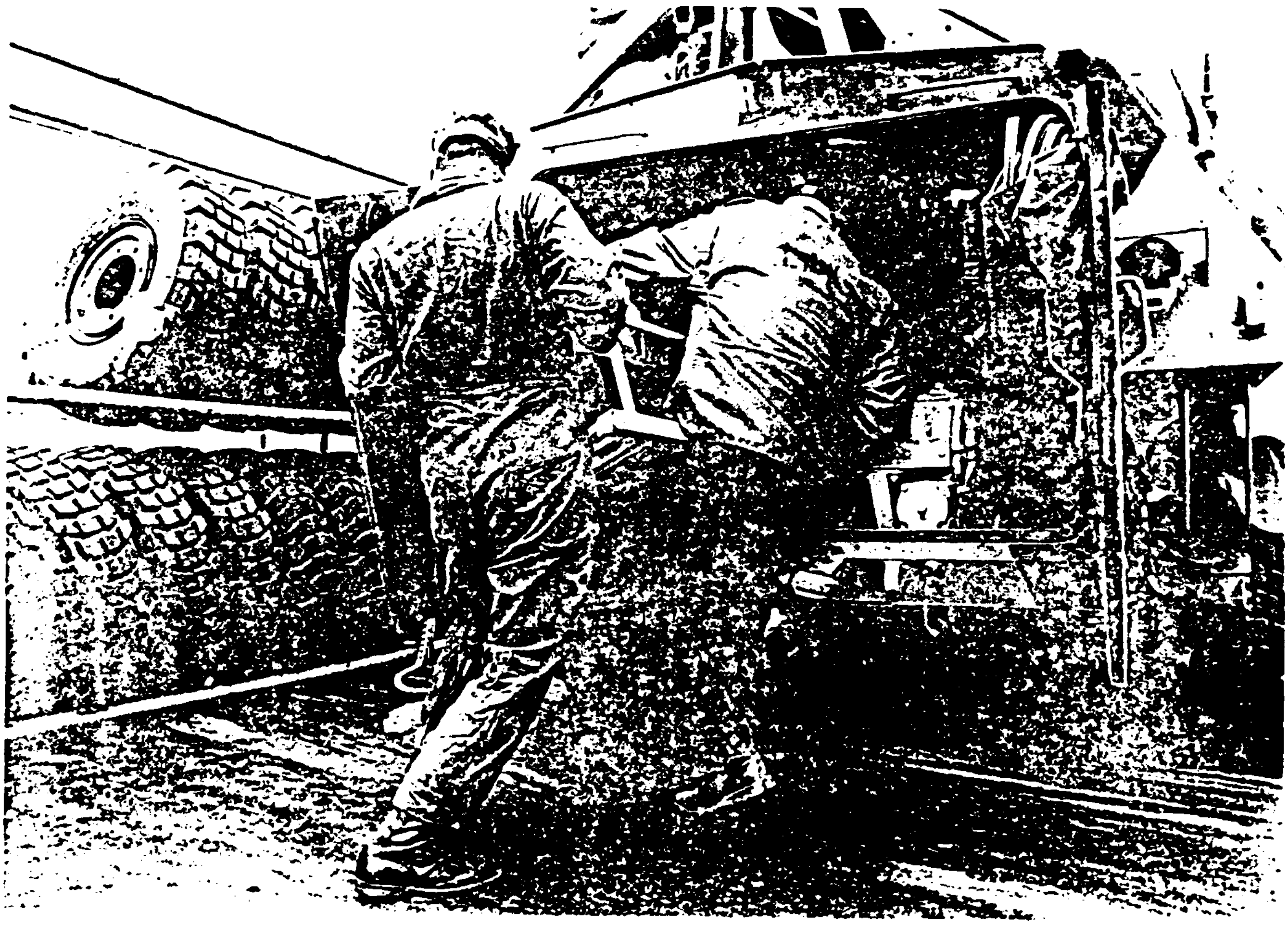

Figure 14. Crew members loading the APU onto its storage rack.

APU onto the carriage rack using the crane and some type of attachment device. Should this solution be implemented, the APU attachment device should be permanently attached to the APU to avoid its loss.

External storage. Forty percent of the crew reported that stowing the tow bar on the upper deck of the vehicle was hazardous due to its weight (approximately 200 lb (91 kg)). In fact, the heaviest equipment (tow bar and rear spades) stored outside of the vehicle, is stored on the upper deck while the lighter equipment (e.g., jerry cans, handtools, accessory bags, etc.) is stored above the sponson on the sides of the vehicle. Figure 15 shows the lighter equipment stored on the side of the LAVM/RV. The tow bar and rear spades should be stored above the sponson on the side walls in order to make lifting injuries less likely and to decrease the time required to stow the equipment. Lighter equipment should be stored on the upper deck, especially handtools and other light accessories. Jerry cans might be stored behind the commander's hatch. This would also provide greater protection to the lighter and less durable equipment from objects, such as trees, brushing the sides of the vehicles.

Workspace

Workbench. The crews rated the usefulness of the workbench as borderline (mean rating, 3.0). Moreover, many workbench features were rated as inadequate, including legroom when seated (mean rating, 2.1), seating position (mean rating, 2.5), and overall comfort when seated (mean rating, 2.5). Figure 16 shows the workbench unfolded (46.75 x 20 in (118.75 x 51 cm)). In interviews, crew members felt that the workbench would not be used. Crew members could not envision performing repair work on small components; the only type of work that could be performed at the workbench. This is because most field maintenance involves the removal and replacement of the entire component. Moreover, crew members stated that the lack of legroom made sitting at the workbench very uncomfortable and difficult to leave the seat for needed tools (seat to wall width 12 in (30 cm); workbench to floor height, 24 in (61 cm)). Thus, they preferred to work outside of the vehicle. Removing the workbench from the vehicle would provide additional legroom and storage space for personal gear.

Fire suppression nozzles. Four data collectors and three scenario controllers reported that the fire suppression nozzles were pointed into mechanics' faces when they are sitting in the mechanic's seat. This may be hazardous. Even though the fire suppression reservoirs are filled with Halon 1301, a breathable substance, the system propels the gas at 360 psi. At this pressure level anything else in the air in front of the mechanic's face, including dust in the fire suppression nozzles, is likely to be blown directly into the eyes of seated crew members. The nozzle would be only 20 in (51 cm) away from the face of a person of the 50th percentile anthropometric body size. It is highly recommended that the nozzles be directed away from the crew's faces.

Driver's seat. The two vehicle commanders reported that their feet could be injured beneath the driver's seat. Figure 17 shows the hazard for the commander as the driver's seat descends. The seat is driven hydraulically and descends rapidly with a force coinciding to the driver's body weight. The greatest potential for injury occurs when the crew must button up rapidly. The driver must lower his seat entirely in order to close his hatch. The commander may remain standing in a crouched position with his feet possibly in the hazardous area. The back of the driver's seat should be guarded to prevent the commander's foot from being positioned beneath the seat.

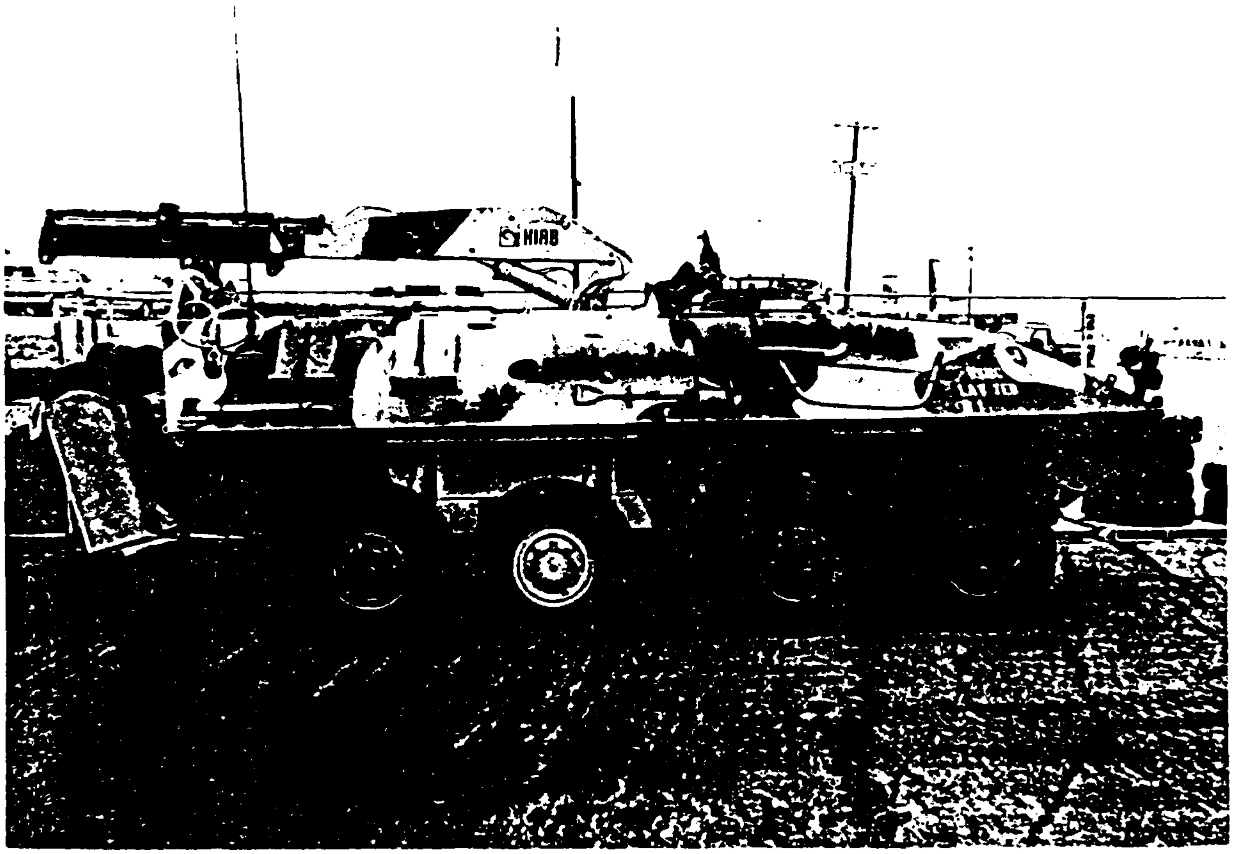

Figure 15. Lighter equipment is stored on the side of the vehicle while heavier equipment is stored on the upper deck.

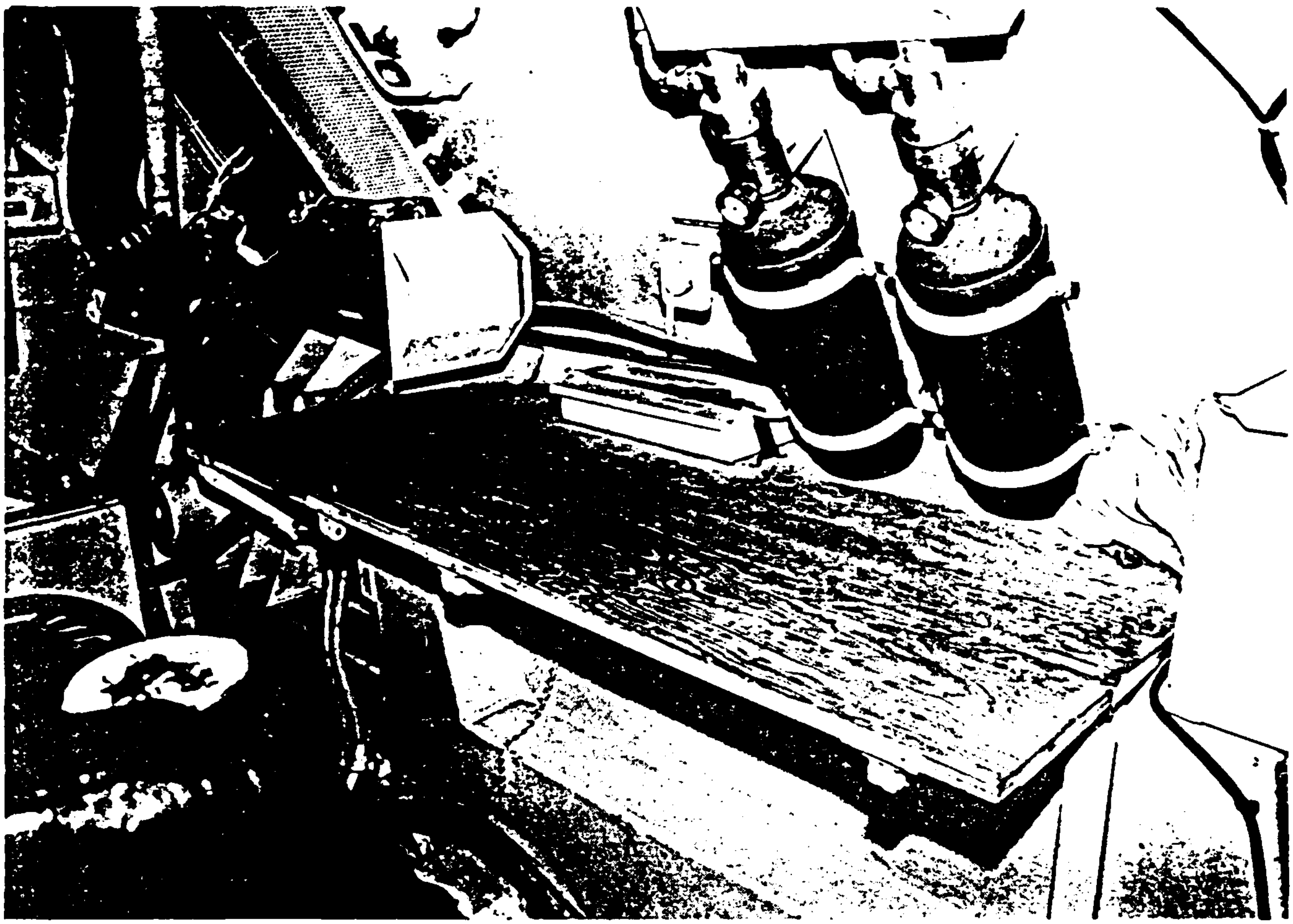

Figure 16. The workbench.

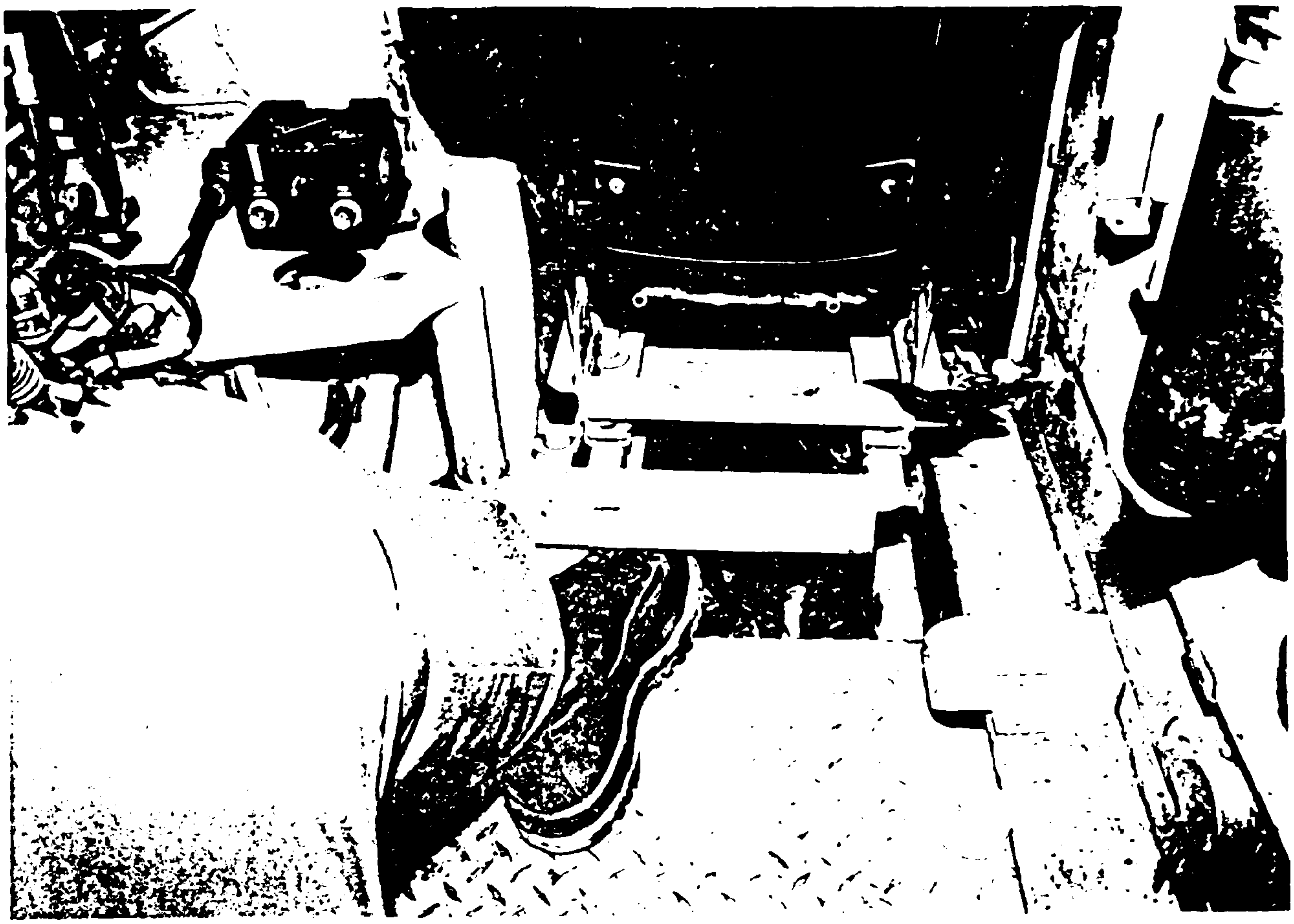

Figure 17. The driver's seat may descend on the commander's foot.

The drivers of the vehicles reported that their seats raise too rapidly and that they may be injured by striking their heads on the closed hatch. The upward adjustment occurs so rapidly and forcibly, once the seat adjustment lever is moved, that selecting a height between fully up or fully down is extremely difficult. It is recommended that the hydraulic pressure provided for seat adjustment be reduced.

Mechanic's seat. The crews rated the comfort and protection from vibration of the mechanic's seat as borderline (mean ratings, 2.7 and 3.3, respectively). Moreover, the seat is also the workbench seat for which the crews rated the legroom as inadequate (mean rating, 2.1). The seat and back padding are approximately one-half inch (1.3 cm) thick and have the same length and width dimensions (39.50 x 13.50 in) (98.8 x 33.8 cm)). The seat and back pads are at right angles to each other. Bolted to the vehicle's body, the seat has no suspension device. Thus, most vertical vibration must be absorbed by very little padding in the seat. Thicker seat and back padding, and a sloping seatback would help distribute the rider's weight across more padding and reduce the effects of vibration. The seat should also have a suspension system.

Rigger's seat. Crew members, having used the rigger's seat, rated the vertical seat adjustment as borderline (mean rating, 3.3). During the test the rigger usually traveled seated on the upper deck. Moreover, the riggers preferred working outside of the vehicles. The rigger's station was never used as a workspace for the following reasons:

1. The seat faces rearward so that vehicle acceleration and braking become uncomfortable sensations,
2. There are too many obstructions to view tasks from the periscopes or from the open hatch,
3. There is very little legroom; the rigger's seat is only 19.5 in (49.5 cm) from the winch spool,
4. The rigger's seat is unprotected should a wire rope failure occur.

The current designs of the rigger's station and the remote winch controls do not provide the rigger with any protection from the danger of wire rope failure. Because a 100 ft (30.5m) remote winch control wire is impractical, controlling the winch safely from outside the vehicle is difficult. The safest location for the rigger to control the winch is from inside the vehicle. This would require:

1. Modification to the rear doors so that the doors can remain closed during winching,
2. A protective housing over the winch drum and cable to protect the rigger from wire rope failure inside the vehicle,
3. Modification to the rigger's periscopes so that the rigger has a view of the area and wire rope immediately behind the vehicle; iaddition, the rigger should have an unobstructed view of the supported vehicle.

Observing riggers perform tasks suggests that they do not require a 360^{o} view from the rigger's periscopes. Moreover, the rigger's view is obstructed by the vehicle due to the periscopes' center location on the upper deck, which also obstructs his view of the crane boom in operation alongside of the vehicle. Thus, it may be advantageous to have the rigger's periscopes positioned on or above the rear doors, facing rearward. This would not only provide the rigger with an unobstructed rearward view but also eliminate the need for a rigger's hatch and periscopes on the upper deck.

Hydraulic hoses. Two crew members reported that their feet had become entangled in hydraulic hoses. Figure 18 shows the winch drive motor and hydraulic hose assembly next to the rigger's seat. Hoses that are unprotected in passageways are a tripping hazard. Moreover, the service life of the hoses and fittings are reduced when they are continually bumped and abraded. The winch drive motor hydraulic hoses should be protected.

Donning room for MOPP clothing. The crews rated the room at their stations for donning NBC MOPP clothing as borderline to inadequate (mean ratings all stations, 2.8, rigger's station, 2.3). It is very likely in the future that chemical and biological agents will be used as weapons based on US government knowledge of the arsenals of potential adversaries. Thus, crews should be able to don MOPP protective equipment at their stations. Given the space limitations within the LAVM/RV, the only solution may be to provide additional secure storage space that increases the open space available at crew stations.

Fuel transfer hoses. Seventy percent of the crews reported hazards associated with the fuel transfer hoses. The hazards involve the possibilities of fuel spillage, fumes, and collision between vehicles on rough terrain. The blue hose for fuel transfer from the LAVM/RV fuel tank to the fuel pump (approximately 8 ft in length (243.8 cm)) requires an additional 4 ft (121.9 cm) of length . This will allow the hose to extend well below the hose ports on the fuel pump and tank, thus avoiding spillage and the resulting fumes. The black hose for fuel transfer from the fuel pump to the supported vehicle (approximately 15 ft in length (365.8 cm)) requires an additional 15 ft (457.2 cm) of length. This will allow vehicles to be positioned for fuel transfer at safe distances in order to avoid collision while maneuvering on rough terrain. Storage for the fuel transfer hoses might be provided by tubes mounted on the sides of the vehicle.

Amphibious propellers. Figure 19 shows one of the propellers at the rear of the vehicle that are used for amphibious operation. The propellers are unguarded and extend 1 in (2.5 cm) beyond the edge of the sponson and 2 in (5 cm) beyond the outer edge of the rear wheel. The propellers are likely to be out of the sight of personnel walking around the corner of the vehicle from the rear. Moreover, the large open space surrounding the propellers increases the chance that objects might collide with the blades when they are spinning. It is in close quarters, such as on naval ships, that the propellers might be engaged while personnel are in the area. The propeller blades should be guarded.

Ventilation and Fumes

Ventilation. Crews rated the vehicle ventilation as borderline or inadequate, regardless of whether or not hatches were open and the vehicle was moving. (See questionnaire item 18.) Mean ratings ranged from 3.3 to 1.9.) Daytime temperatures during the human factors assessment were mild, ranging from 56 to 76°F (13.3 to 24.4°C). In the rear two-thirds of the vehicle there is only one air/heating vent. This vent is shown in Figure 16 as the light gray duct to the left of the workbench. The single vent does not only limit the amount of moving air available to the crew, it also poorly directs air. The air/heat blows directly onto the mechanic seated at the mechanic's seat (mechanic's chest to vent port is 18.5 in (46.9 cm)). This deficiency also accounts for the crews' borderline rating (mean, 3.3) of the heating system. An additional air duct and vent should be positioned in the rear of the vehicle crew compartment. The air/heat should be widely dispersed and not blow directly on any crew members.

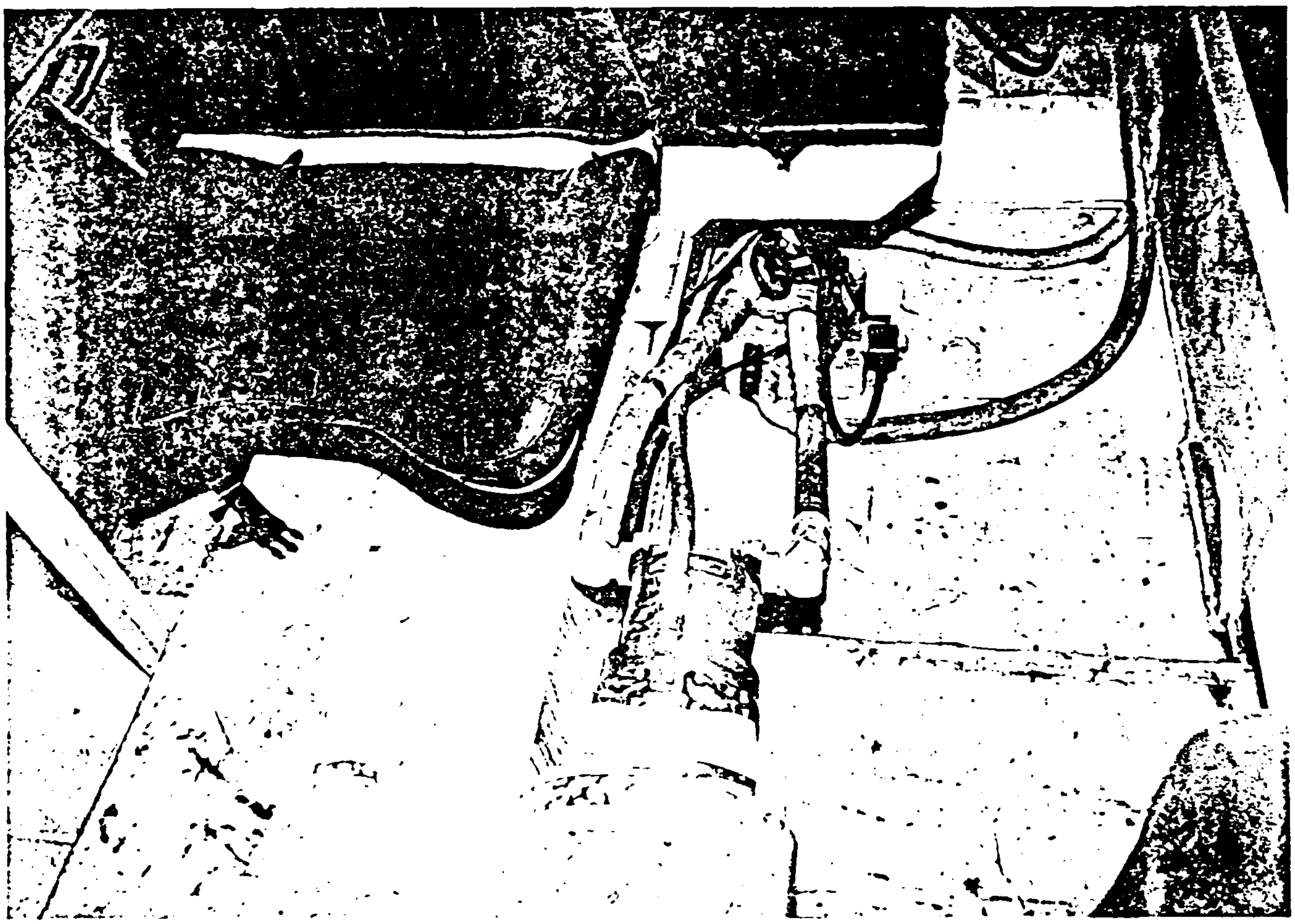

Figure 18. The hydraulic hoses of the winch drive motor are unprotected and are tripping hazards.

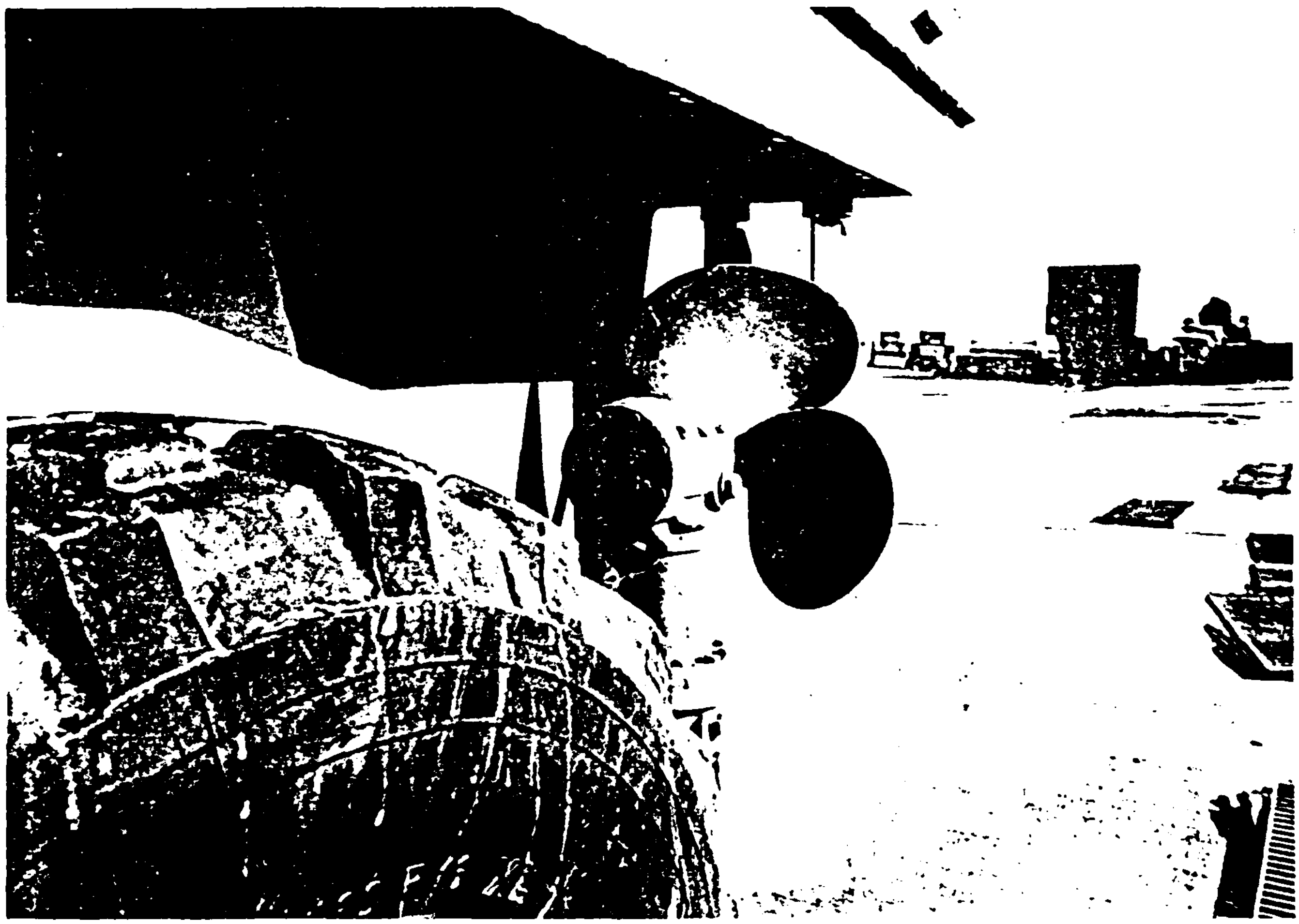

Figure 19. The amphibious propeller extends beyond the sponson and wheel.

Fume removal. The crews rated the removal of fumes by the ventilation system as borderline (mean rating, 3.3). During the first days of the test, three crew members in the Army vehicle became sick from fumes. The source of the fumes was unknown, however, the lack of multiple air vents in the rear of the vehicle to circulate fresh air probably contributed to the problem.

Illumination

Blue lights. Crew members rated the interior blue lights required by the Army Secure Lighting Program at several crew stations as borderline to inadequate. (See questionnaire item 23. Mean ratings ranged from 3.1 to 2.2.) The blue lighting did not provide enough light to perform tasks at two critical stations, which are the bilge pump (mean rating, 3.0, borderline) and the crane on-board control station (mean rating, 2.2, inadequate). Blue lighting should be provided directly over the bilge pump. Enlarging the symbols on the on-board crane controls, as discussed earlier, should make the controls easier to use under blue lights.

Visual Coverage

The crews rated the visual coverage of surrounding terrain and objects from the driver's periscopes as borderline (mean rating, 3.0). Periscope position to avoid blindspots was also rated as borderline (mean rating, 2.8). The drivers reported that blindspots occurred along side and to the rear of the vehicle. Rear view mirrors were positioned approximately 84 in (213.3 cm) in front of the driver. At this distance the driver had great difficult recognizing images reflected in the mirrors. Poor rearward visual coverage is a recognized problem for military vehicles and in the present configuration of the LAVM/RV, it is difficult to improve. However, it is recommended that the rear view mirrors be moved rearward on the vehicle sides to as close to the driver's periscopes as is necessary to improve his view. The rear view mirrors should also be hooded to prevent adversaries from detecting reflections.

Communications

During four recovery and self-recovery scenarios riggers and commanders outside of the vehicle had great difficulty communicating with the vehicle driver. Fifty percent of the crews reported in interviews that it takes two people to direct the driver; one person hand signals from the rear of the vehicle while the other hand signals from the front. Often, rocks were thrown at the front of the LAVM/RV to attract the driver's attention. The difficulties of hand signaling directions to the driver increased the time required to position the vehicle by an estimated 50 percent. Vehicle commanders suggested that a 20 foot spaghetti cord and intercom positioned at the rear of the vehicle jacks would allow the rigger to use the CVC system from outside the vehicle. This would allow the rigger to have direct communication with the driver during backing of the vehicle and attaching of the tow bar.

Design For Maintenance and Tool Supply

Service access panels. Access to the power pack through the interior panel was rated as borderline by the crews (mean rating, 3.1). The panel is located along the right side and behind the driver. The driver must open the panel to check the transmission oil and various filters. The panel is held in place by four "wing type" bolt assemblies. The assemblies have three parts which separate and are easily lost. Because of this difficulty, crews hesitated to remove the panel. In the future, it is likely that proper maintenance inspections of the transmission oil will not occur due to this difficulty. Single part devices that can be easily handled should be provided.

Transfer case "doghouse" housing. Removal of the transfer case doghouse housing was rated as borderline by the crews (mean rating, 3.4). The doghouse housing was the portion of the vehicle's hull covering the transmission housing. There is only two inches of clearance space for tools and hands between the doghouse and vehicle interior body panels. Moreover, mechanics reported that the transfer case service plugs were difficult to access due to a lack of clearance space once the doghouse was removed. Special tools might be designed that can be used effectively in such limited space.

Tool supply. Table 5 is a list of additional tools that crews reported were needed for tasks. Crews were borrowing tools and supplies from each other's vehicles throughout the testing. This indicated that additional consideration should be given to the numbers and types of tools actually supplied to the crews.

NBC decontamination tools were not included in the LAVM/RV tool supply. Maintenance and recovery personnel may have to protect themselves from trapped chemical and biological agents that may collect in the hinges, fasteners, ridges, and greasy areas of supported vehicles. Agents are likely to remain on vehicles even after major decontamination has occurred. In these situations the crew will need ways to detect agents, to protect themselves, and tools to remove agents.

Power Take-Off (PTO) manifold. Early in the test, vehicle maintenance personnel thought all hydraulic hoses on the PTO manifold were attached and secure. The hydraulic fluid return line for the winch drive motor, however, was not fastened, which closed its safety valve. When the PTO was engaged the input line to the winch drive motor was then subjected to an overpressure which caused the drive motor seal to burst. Hydraulic fluid sprayed into the crew compartment. The hydraulic hoses in the PTO manifold are short (6 to 8 in (15.2 to 20.3 cm)) and stiff. It is difficult for personnel to tell whether or not the hoses are attached because the stiff hoses do not feel loose. The length of the hoses should be increased until they feel less stiff and mechanics can detect by touch whether or not the hose is loose. In addition, the hose coupler valve should give a highly audible click when it has been appropriately attached.

Other maintenance concerns. Other maintenance concerns were reported during the human factors assessment, however, due to the mechanics' limited experience with the LAVM/RV, further investigation of these concerns will be required. The maintenance concerns include:

Table 5

Additional Tools Needed by LAVM/RV Crew

Quantity Supplied	Quantity Needed	Tool Description
1	2	Short handled shovel
1	2	Sledge hammer
1	2	Sledge hammer
0	1	Matics pick
2	4	Common hammers
0	4	Drifts (to drive pins out)
0	4	5-ton capacity jack stands
0	1	30-ton capacity blocks
2	4	20-ton capacity blocks
2	4	10-ton capacity blocks
2	4	6-ton capacity blocks
2	4	20-ton capacity shackles
2	4	10-ton capacity shackles
2	4	6-ton capacity shackles
10	30	Tow bar pins
0	1	Electrical extension cord
0	2	20 ft (6.1m) spaghetti cord for intercom/CVC
0	1	Coupler for spaghetti cords
0	1	75 ft (22.9m) control cord for winch remote controls
0	1	Line leveler device for winch reel (for spool in cable alignment
0	1	Winch free spool brake
0	1	Ste-ice battery and electrical equipment tester
0	Unknown	NBC decontamination kit (brushes, sprayers, chemicals, detector, etc.)

1. Two different bolt facets (6 and 12 point facets) are used on several vehicle components. This will require duplicate wrench sets and increase the time required to performance maintenance.

2. The power pack will have to be removed in order to service the alternator. It is not yet known whether or not this will be a frequently performed task.

3. The spanner notches on the transfer case output shaft tunnel are not deep enough to safely insert a spanner or screwdriver. When mechanics apply force to the spanner wrench inserted into the notches, the spanner wrench often slips out of the notches. The mechanic may be injured. The time to perform the task is increased.

Operator Manuals

Fifty percent of the crewmen reported in the structured interviews that information should be added to their operator manuals. The topics included:

1. Additional information is required describing all LAVM/RV equipment applications. For example, the preliminary operator's manual describes how to operate the APU generator/welder, however, there is no description of how to use the APU for various tasks.

2. Additional information is required about unique recovery techniques using LAVM/RV equipment. For example, the preliminary operator's manual describes how to operate the crane yet does not describe how the crane and winch might be used to anchor and stabilize the LAVM/RV while it traverses a steep slope. Another example might be how to use the side stabilizers as jacks for replacing tires.

3. Additional information is required about rigging force and weight calculations. Rather than having to reference ST 17-20-22, The Field Recovery Manual, include a summary of the formulas that should be calculated in order to rig safely in the LAVM/RV operator's manual.

Training Needs

Seventy percent of the crewmen reported the need for additional topics to be included in training for LAVM/RV operators. During testing, the crew of the LAVM/RV rigged the winch wire rope through the upper port and crane boom block to a tree stump on the side of a slope. The crew hoped to use this technique to back their vehicle out of mire. Unfortunately, the crane boom block and eye broke and the attempt to perform the self-recovery failed. The crew felt that the failure could have been avoided had they been given additional training concerning the capabilities, uses, and limits of their equipment used for special situations. Crewmen suggested additional training needs, including:

1. Determining rigging force and weight requirements as they pertain to the use of LAVM/RV equipment,
2. Determining when it is appropriate or inappropriate to use the winch and the crane, alone or in combination,
3. Actual field demonstration of LAVM/RV capabilities.

DISCUSSION

A number of human factors deficiencies were found during the OT II assessment. Fortunately, all of the deficiencies appear to be correctable and well within the design constraints of the LAVM/RV. There were also many well designed features of the vehicle. For example, USMC mechanics reported that the LAV is the easiest type of vehicle intheir fleet to maintain. The purpose of this study, however, was to identify human factors deficiencies. The deficiencies may have resulted from the effort to build a recovery vehicle capable of performing a variety of maintenance and recovery tasks in the field. This places many demands on the vehicle and its crew. Thus, additional thought should be given to the arrangement of vehicle features and their effect on crew performance. Table 6 lists a summary of recommendations made for the vehicle features described in the results section. The recommendations generally concern interior vehicle features, exterior vehicle features, and vehicle auxiliary equipment affecting crew performance and safety.

The interior vehicle features that should be given the highest priority for change are the rigger's station and the winch. Work performance problems included the obstructed views, the time required to spool in the wire rope, and the need for frequent inspections during the wrapping of the wire rope. Safety problems included the lack of protection from wire rope failure for the rigger, and the lack of a free-spool brake. A decision must be made concerning the advantages of having a remote winch control, especially since the rigger would need to be 100 ft (30.4m) away from the LAVM/RV in order to be outside of the danger area specified by ST 17-20-22. Should planners decide that the rigger should be protected from wire rope failure by operating the winch from inside the vehicle, several changes need to be made to the rigger's station. An unobstructed rearward view of the wire rope and the supported vehicle must be provided (a 360^{o} view may not be necessary). The rigger should be able to view the winch spool and be protected from wire rope failure inside the vehicle. The rear doors may not have to be closed to provide protection if other devices are used, however, closing the rear doors during winching will provide substantial protection. A free-spool brake and multiple speed control for the winch should be provided.

Providing viewing ports and/or periscopes at the rear of the vehicle may also make eliminating the rigger's hatch possible. Since ingress and egress through the hatch, in its present location, will always be obstructed by the crane boom and relocating the hatch may require additional changes to the interior, the advantages of retaining the hatch should be seriously questioned.

The exterior vehicle features that should be given the highest priority for change are the storage locations for auxiliary equipment. The frequently used and heaviest equipment, the tow bar and rear spades, are stored on the upper deck. The less frequently used and lighter equipment, large handtools and jerry cans, are stored on the sides of the

Table 6

Summary of Recommendations

Ingress-Egress

Lower pintle below rear doors.

Add pivot hinge for driver's hatch.

Add pivot hinge for rigger's hatch.

Raise or change position of machinegun mount.

Increase diameter of hatches.

Add padding around hatch openings.

Remove obstructions to vehicle passageways.

Add nonslip surfaces to grill and steps/handholds.

Protect hatch seals.

Caution labels for hatch seals.

Cautions about hatch seals in literature and training.

Workspace

Eliminate workbench.

Change spray direction of fire suppression nozzle.

Add foot guard at rear of driver's seat.

Slow driver seat rate of adjustment.

Add padding and suspension to mechanic's seat.

Decide to keep or eliminate rigger's hatch.

Control Stations

Relocate gear shift and transfer case lock levers.

Add a "T" handle for the transfer case lock lever.

Relocate turn signal lever.

Place engine oil pressure and temperature gauges in driver's line of sight.

Add a hot hydraulics gauge and signal.

Enlarge on-board crane control symbols.

Relocate on-board crane control symbols.

Add a winch wire rope port to rear doors.

Add a winch spool brake.

Add a winch line leveler.

Storage Space

Add secure storage space.

Add a carriage rack to the APU storage rack.

Store tow bar & rear spades above sponson.

Ventilation and Fumes

Add rear ventilation port.

Table 6 (cont'd)

Workspace (cont'd)	Illumination
Cover winch drive motor hydraulic hoses.	Add blue lights over bilge pump.
Provide room to don MOPP clothing.	Visual Coverage
Lengthen fuel transfer hoses.	Move rear view mirrors closer to driver.
Guard amphibious propellers.	
Communications	Operator Manuals
Add a 20 ft (6.1m) CVC spaghetti cord and a CVC jack at the rear doors.	Add information describing all equipment applications.
Design For Maintenance	Add information on unique recovery techniques using LAVM/RV equipment.
Simplify power pack access panel latches.	Add information about rigging force and weight calculations.
Provide space to access transfer case doghouse.	Operator Training Needs
Provide additional tools and NBC decontamination equipment.	Determining rigging force and eight calculations.
Lengthen PTO manifold hoses.	Determining appropriate use for winch and crane.
Use only of bolt facet.	Actual field demonstrations of LAVM/RV capabilities.
Deepen spanner notches on transfer case shaft tunnel.	

vehicle. The heavier equipment should be stored on the sides of the vehicle to lessen the likelihood of injury to personnel lifting and lowering the equipment. Moreover, this should reduce the time needed to stow the heavier equipment. The heavier equipment is also more durable than is the lighter equipment and is less likely to be damaged by objects hitting the vehicle sides. Consideration should be given to storing more equipment in protective lockers on the upper deck of the vehicle. Crews suggested that the winch might also be located on the upper deck below the crane boom (since the vehicle seems long enough and heavy enough to withstand the change in the center of gravity during winching).

The auxiliary equipment that should be given the highest priority for change are the APU and its storage rack. Injury to personnel is likely during the lowering and lifting of the APU. The weight (approximately 360 lb (163.29 kg)), height of lift for loading (45 in (114.3 cm)), and location of the APU make it impossible for personnel to load it safely according to MIL-STD 1472C. A storage rack and procedure should be developed so that the crane can be used to load and unload the APU.

The developing trend seems to be one where recovery vehicles are being manufactured to service a fleet of like vehicles rather than the manufacture of general recovery vehicles. This trend is supported by the development of the AMTRAC-LVTR7 and the LAVM/RV. Thus, designers of recovery vehicles should consider that:

1. General MIL standards for combat vehicles may not be appropriate for highly versatile recovery vehicles,
2. Recovery vehicles and crews are likely to operate in harsh environmental conditions that have stopped or trapped other vehicles,
3. Recovery crews will need specialized training pertaining to the specialized equipment on the vehicle beyond general recovery training.

Training needs were difficult to assess during testing due to the highly experienced recovery crews used to man the vehicles. Their experience probably provided them with insights to training needs, however, it also probably helped them to avoid difficulties. The difficulties would have signaled possible training needs. Regardless, it was found that crew members needed additional training on the applications and special techniques for which the LAVM/RV equipment might be used. In addition, crew members need to know the limitations of the equipment when special applications and techniques are used.

Unlike other vehicles of the LAV family, the LAVM/RV is not in a final production phase and improvements can be made. Individuals that have experience in maintaining and operating the family of light armored vehicles also have high regard for the vehicle's qualities. Correcting the human factors deficiencies in the LAVM/RV is very likely to improve the crews' performance and increase the crews' regard for their vehicle.

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