REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704 - 0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reveiwing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	12/01/96	CSERIAC Paper (1Oct 95 -1 Dec 96)

4. TITLE AND SUBTITLE
Implications of Crew Resource Management (CRM) Training for Tank Crews

5. FUNDING NUMBERS
SPO900-94-D-0001

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8. PERFORMING ORGANIZATION REPORT NUMBER
CP-96-002

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
This paper was presented at the Interservice/Industry Training System and Education Conference (I/ITSEC) in Dec 96, and is published in that meeting's proceedings on CD-ROM

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Statement A: Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
DISTRIBUTION A

13. ABSTRACT (Maximum 200 words)

Mission effectiveness of US Army tank crews may be enhanced by applying principles of Crew Resource Management (CRM). A recent study of the US Army Safety Center Database identified a number of tank accidents, particularly during non-combat operations, that involved deficiencies in crew coordination. In addition, data from the Center for Army Lessons Learned indicates that CRM may play a role in fratricide accidents. In the late 1970s, findings of crew coordination problems in aviation accidents created the impetus for mandated CRM training for aircrews. The purpose of this paper is to explore evidence of tank CRM-related problems and investigate the possible applications of aviation-derived CRM training to tank crews. CSERIAC's analysis of crew coordination-related tank accidents suggests that the application of CRM principles to tank crews may increase mission effectiveness and operational safety. Several factors support the application of CRM principles to tank crews. These factors include increases in automation, the criticality of shared perceptions, possible information overload, and increasing requirements for team decision-making on the digital battlefield. Developing a comprehensive strategy to improve tank CRM appears to be timely. Although surface similarities of aircraft and armor crews imply that CRM training courses could be directly applied from the air cockpit to the ground vehicle, it is important to understand the differences between these two crew environments and to appreciate the unique CRM needs of tank crews.

14. SUBJECT TERMS
Human System Integration, Human Factors Engineering, Distributed Simulation, Transfer of Training, Crew Coordination, Accident Statistics, Fratricide, Tanks, Aircraft, Safety, Cockpit or Crew Resource Management, Situational and Battlefield Awareness, Structured Approach

15. NUMBER OF PAGES
10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

DTIC QUALITY INSPECTED 1

Presented at I/ITSEC
December, 1996

IMPLICATIONS OF CREW RESOURCE MANAGEMENT (CRM) TRAINING FOR TANK CREWS

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ABSTRACT

Mission effectiveness of US Army tank crews may be enhanced by applying principles of Crew Resource Management (CRM). A recent study of the US Army Safety Center Database identified a number of tank accidents, particularly during non-combat operations, that involved deficiencies in crew coordination. In addition, data from the Center for Army Lessons Learned indicates that CRM may play a role in fratricide accidents. In the late 1970s, findings of crew coordination problems in aviation accidents created the impetus for mandated CRM training for aircrews. The purpose of this paper is to explore evidence of tank CRM-related problems and investigate the possible applications of aviation-derived CRM training to tank crews. CSERIAC's analysis of crew coordination-related tank accidents suggests that the application of CRM principles to tank crews may increase mission effectiveness and operational safety. Several factors support the application of CRM principles to tank crews. These factors include increases in automation, the criticality of shared perceptions, possible information overload, and increasing requirements for team decision-making on the digital battlefield. Developing a comprehensive strategy to improve tank CRM appears to be timely. Although surface similarities of aircraft and armor crews imply that CRM training courses could be directly applied from the air cockpit to the ground vehicle, it is important to understand the differences between these two crew environments and to appreciate the unique CRM needs of tank crews.

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Presented at I/ITSEC
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INTRODUCTION

Effective coordination of tank crews, both within an individual tank crew and among the "larger team" on the battlefield, is essential for mission effectiveness and crew safety. Consider the following excerpt from a US Army Safety Center (USASC) accident report:

> The lead (#1) tank's commander noted an increase in the headwind and a corresponding increase in the dust generated by his tank and dust blowing into his face. He therefore instructed his driver to slow the tank's speed to 4-5 miles per hour. The following (#2) tank's commander and driver were not aware that the lead tank had slowed, and they maintained march speed of 10 miles per hour through the degraded visibility. The driver of tank #2 saw tank #1 at 40-50 feet and reacted by applying his brakes sharply. His commander attempted to use the TC override switch to rotate the turret to the right to clear the gun tube of the rear of tank #1. At nearly the same time, the commander of tank #1 saw tank #2 emerge from the dust, overtaking his tank from the rear. He yelled at his driver to speed up, and for everyone to brace for a crash. All attempts to avoid a collision failed. The end of the gun tube of tank #2 struck the right rear corner of the engine exhaust cover doors of tank #1. The impact drove the main gun tube of tank #2 aft, jolting the gun out of the battery and shearing all 16 recoil mechanism retaining bolts. The gun continued to the rear where it struck the gunner in the chest, crushing him between the gun breech and the turret wall, killing him instantly [at the time of the accident, the gunner was out of his seat, removing debris from the turret floor].

Nearly two decades ago, records identifying crew coordination as a critical accident factor in the aviation environment created the impetus for training crew coordination, predominantly called Crew Resource Management (CRM). Lauber (1987) defines CRM as the effective use of all resources, including human resources (i.e., liveware), information resources (i.e., software, in contrast to its use in the computer domain), and equipment resources (i.e., hardware). The goal of CRM training is to prevent accidents related to poor crew coordination (FAA, 1995). Carroll and Taggart (1987) reported that poor CRM was a causal factor in 60% of the fatal air carrier mishaps from 1970-1980, and 80% of the fatal accidents when statistics included military, corporate, and general aviation aircraft. These lopsided figures, punctuated by a number of archetypal CRM-related accidents, led to the implementation of CRM training in both military and civilian aviation.

NASA and Federal Aviation Administration (FAA) CRM training assessments revealed that aircrew attitudes toward CRM and flightdeck management significantly improved after initial indoctrination. With recurrent emphasis, practice, and evaluation, significant changes in aircrew behavior transpired. The FAA (1995) states that, "CRM trained crews operate more effectively as teams and cope more effectively with nonroutine situations" (p. 3).

Despite CRM's positive impacts in aviation, no large body of research addressing crew coordination training for tank crews exists. Huey and Wickens (1993) state, "To date, no investigation has been carried out on the extent and nature of leadership and crew coordination problems in tank crews. . . . Priority should be placed on conducting research to determine if such training is applicable to tank crews" (p. 274).

Purpose

The purpose of this paper is to explore tank CRM-related problems and possible solutions. CSERIAC also investigated the possible applications of aviation-derived CRM curriculum to tank crew training.

METHOD

CSERIAC investigated the following data sources for tank crew coordination research and training programs.

Background Search of Informational Databases

CSERIAC searched the DTIC DROLS, CD-ROM, and Work Unit Information Summary; MATRIS FAA, Human Systems Integration, and Work Unit; Ei-Compendex* Plus; NASA Recon; PsycINFO; and SciSearch databases. We also searched the WorldWide Web. Little scientific literature dealing directly with training tank crew coordination was identified.

Subject Matter Expert Opinion

Lacking significant findings related to tank crew coordination training, we consulted subject matter experts in industry, academia, and the military (including tank crewmembers) to clarify CRM considerations in tanks. We compared expert opinion with our research findings to determine the extent of congruence.

Tank Accident/Casualty Database Search

CSERIAC identified three databases to search for crew coordination-related tank accidents and losses. These databases included the Walker Crew Casualty Database maintained at the Survivability/Vulnerability Information Analysis Center (SURVIAC), the CREWCAS Tank Crew Injuries Database, and the USASC Database. After closer study, we determined that only the USASC database had the categorization and currency needed for our effort. The search of the USASC database included all reported unlimited/unclassified tank accidents from the past 11½ years. We recognize that the security distribution limitation (i.e., unlimited/unclassified) may have affected the results of the database search.

Consultation with CALL

CSERIAC consulted the Center for Army Lessons Learned (CALL) to acquire lessons-learned on crew coordination. We were particularly interested in accidents involving fratricide, since such accidents sometimes involve crew coordination problems.

RESULTS AND DISCUSSION

Findings from Aviation CRM

Before the initiation of aviation CRM training, crew coordination skills lacked clear organization, emphasis, practice, and evaluation. Some crew training programs trained with a team concept in mind, but accident records demonstrated a need to organize, emphasize, practice, and evaluate team skills *specifically*. Therefore, the FAA, airlines, and military all began implementing formal aviation CRM programs.

CRM's Definition, Purpose and Dimensions. CRM is the application of team management concepts to the crew environment, and requires effective use of all available human, hardware, and information resources (FAA, 1995). The aircrew training manual for both the OH-58A/C and OH-6 helicopters (US Army, 1993) defines crew coordination as "crew member interaction (communication) and actions (sequence and timing) necessary for the efficient, effective, and safe performance of tasks" (par. 6-3). CRM averts accidents "by improving the performance of the crew through better crew coordination" (FAA, 1995, p. 4).

FAA CRM Concepts. The FAA (1995) developed a list of CRM subtopics which represent the components of CRM. Variations on these subtopics appear in most other (e.g., airline, military) CRM programs. The FAA lists the subtopics of CRM as:

- Briefings
- Inquiry/Advocacy/Assertion
- Crew Self-Critique
- Conflict Resolution
- Communications and Decisionmaking
- Leadership/Followership/Concern for Tasks
- Interpersonal Relationships/Group Climate
- Preparation/Planning/Vigilance
- Workload Distributed/Distractions Avoided
- Individual Factors/Stress Reduction

Line/LOS Checklist. After training the CRM skills associated with these subtopics, performance of crewmembers may be assessed via the NASA/ University of Texas/FAA Line LOS (Line Operational Simulation) checklist (Helmreich, Butler, Taggart, and Wilhelm, 1995). This checklist facilitates the ratings of observable CRM behaviors by expert observers. Variations of the Line/LOS are used by commercial and military aviation in simulator training. Three examples of the 31 Line/LOS rated behaviors are listed below.

Sample of Line/LOS Behaviors

#1. Team concept and environment for open communications established and/or maintained, e.g., crewmembers listen with patience, do not interrupt or "talk over," do not rush through the briefing, make eye contact as appropriate.

#8. Captain coordinates flightdeck activities to establish proper balance between command authority and crewmember participation, and acts decisively when the situation requires.

#19. Positive and negative performance feedback is given at appropriate times and is made a positive learning experience for the whole crew—feedback is specific, objective, based on observable behavior, and given constructively, e.g., critique of takeoffs and/or landings.

Army CRM Qualities. The US Army Aviation Center organized a list of 13 crew coordination basic qualities (Simon and Grubb, 1995) which are similar to the FAA's subtopics of CRM. These 13 qualities have associated training, practice, and evaluation. They form the core of the Army Aviation CRM program. The 13 basic qualities that crews should exhibit are listed below (Simon and Grubb, 1995, p. B-1-1).

Crew Coordination Basic Qualities

1. Establish/maintain team leadership/crew climate
2. Accomplish pre-mission planning and rehearsal
3. Apply appropriate decision making techniques
4. Prioritize actions and distribute workload
5. Manage unexpected events
6. Provide clear, timely, relevant, complete, and verified statements and directives
7. Maintain situational awareness
8. Communicate/acknowledge decisions/actions
9. Seek supporting information/actions from crew
10. Mutually cross-monitor crewmember actions
11. Crew offers supporting information and actions
12. Practice advocacy and assertion
13. Accomplish crew-level after-action reviews

ACE Checklist. Evaluation of the 13 Basic Qualities is completed with the ACE (Aircrew Coordination Evaluation) checklist (Simon and Grubb, 1995). Similar to the Line/LOS checklist, expert observers rate trainees on crew coordination behaviors via a Likert scale. The ACE uses the 13 Basic Qualities as rating items, providing page-long reference descriptions of each basic quality.

Accident Perspective of CRM. Viewing CRM from a perspective of behaviors that should be avoided, USASC's accident database categorizes inadequate crew coordination and communication in six behaviors. We compiled the following list of these behaviors from Ricketson (1991, p. 8), US Army (1993, par. 6-3) and USASC (1992, p. G-B-27).

1. *Improper action sequence.* Failure of crewmember to execute actions in proper sequence with actions of another crewmember (i.e., improper sequencing and/or timing)
2. *Failure to offer information/assistance/warning.* Failure of crewmember to offer assistance or information that was needed or had been requested previously by the flying (vs. non-flying) pilot
3. *Lack of positive communication.* Crewmember failure to verbally or nonverbally communicate positively (e.g., transmit, acknowledge, confirm) using standard terminology with specific qualifiers
4. *Failure to announce decision/action.* Failure of crewmember to announce a decision or action that affected the ability of another crewmember to perform duties properly
5. *Failure to direct/request assistance.* Failure to direct assistance from another (non-flying) crewmember (e.g., provide airspeed, altitude, engine information or assist with aircraft clearance/control)
6. *Failure to assign responsibilities.* Failure of the pilot in command to assign crew responsibilities properly before (i.e., briefing) and during mission

Outcomes of Aviation CRM Training. At the US Army Aviation Center, a 1992 crew coordination program validation study demonstrated the following (USAAVNC, 1995):

- Reduction of crew coordination errors by 43-100%
- Potential to reduce accident costs by $25 million/year
- Potential to save 12 or more lives per year
- Mission accomplishment improvement of 78%

Realization of such positive outcomes in aviation has confirmed the utility of CRM training. These outcomes suggest that CRM training applied to tank crews can result in safer and more effective operation.

Tank Crew Coordination Accident Analysis

CSERIAC used the six crew coordination failures (listed at the lower left) as part of the search strategy for the USASC accident database (USASC, 1996). Analysis of USASC's accident database revealed that crew coordination problems exist in a significant proportion of tank accidents. Crew coordination failures appeared in 12 of 43 (27.9%) Class A tank accidents during the period of 1 October 84 - 1 April 96. See Table 1 for a description of accident classes (US Army, 1994, p. 4). All accident excerpts cited in this paper were taken from these 12 Class A accident reports.

Table 1. Accident classes and descriptions

Class	Description
A	Property damage $1,000,000/+, Army aircraft or missile destroyed, missing, abandoned, or fatal or permanently disabling injury/illness
B	Property damage $200,000/+ but under $1,000,000, injury/illness with permanent partial disability, or 5/+ people hospitalized from one accident
C	Property damage $10,000/+ but <$200,000, or nonfatal loss-of-work-time injury beyond present shift, or nonfatal loss-time or disability
D	Property damage $2,000 or more but less than $10,000

Our accident analysis is presented in the following series of four graphs. Overall, we expressed our findings in terms of single accident classes (A, B, C, D) and combined accident classes (A-B, A-C, A-D), and in terms of total and crew error accidents.

Figure 1 (below) depicts the proportion of tank accidents involving crew coordination as a percentage of total accidents within a class. Notice that crew coordination-related accidents are proportionately greater for Class A accidents, although Class C accidents have a greater raw number of crew coordination-related accidents.

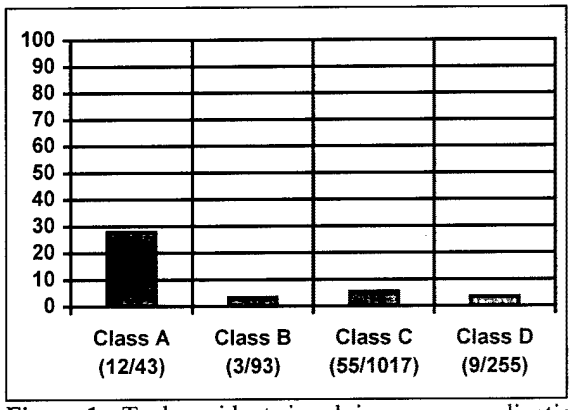


Figure 1. Tank accidents involving crew coordination as a percentage of total accidents within classes

Accidents involving crew coordination problems are also expressed a percentage of accidents that involved general crew error (as opposed to mechanical failure, etc.). Summary graphs for accidents involving crew coordination as a percentage of crew error accidents (within classes) are provided in Figure 2. Again, there are proportionally more Class A crew coordination-related accidents than Class B, C, or D crew coordination-related accidents.

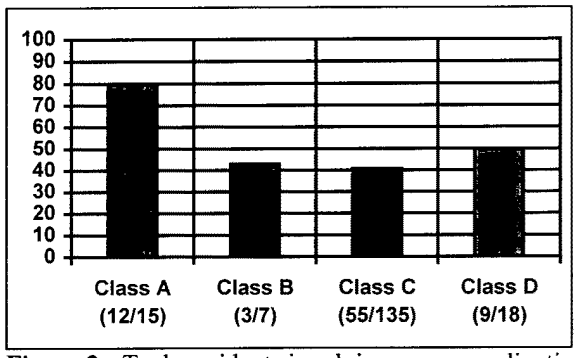


Figure 2. Tank accidents involving crew coordination as a percentage of crew error accidents within classes

Ricketson (1991) reported that 20% of Army aviation (rotary wing) crew error accidents (combined classes A-C) involved crew coordination problems. Class D accident reports were not included in this analysis because they contained incomplete data. This statistic covers the time frame from fiscal years 1984-1989, and identifies 84 rotary-wing accidents involving crew coordination problems out of 413 crew error accidents (these 84 accidents were selected by the USASC because of *clear evidence* of CRM-related problems out of 99 *possible* CRM-related accidents—the remaining 15 accidents were discarded). Ricketson concluded that crew coordination should be integrated into tasks, conditions, and standards. On balance, he cautioned that crew coordination will not solve all crew error problems, and should not be "overdone."

CSERIAC compared Ricketson's (1991) aviation findings with our tank data analysis. We used data on tank crew error accidents and combined data across classes (including classes A-C). Possible tank crew coordination problems appeared in 15 of 22 crew error-related Class A and B accidents, or about 68% of the total. Seventy of the 157 tank crew error Class A, B, and C accidents (44%) involved crew coordination problems. Finally, crew coordination problems appeared in 79 of 175 tank crew error Class A, B, C, and D accidents combined. This equates to about 45% of the total. We compared these figures with Ricketson's (1991) raw data (no records discarded) of 99 crew coordination-related accidents out of 413 crew error accidents (23.97%; slightly higher than the 20% confirmed to involve crew coordination). We used these figures because no records were discarded from the tank search. The results are presented in Figure 3.

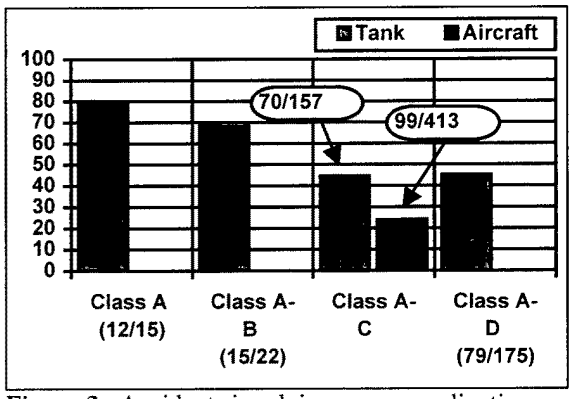


Figure 3. Accidents involving crew coordination as a percentage of crew error accidents combining classes

Finally, Figure 4 illustrates aviation-tank comparisons in the perspective of the total combined-class accidents that involved crew coordination problems. Overall, about 6% of total Class A-C tank accidents involved crew coordination problems, while about 15% of total Class A-C aviation accidents involved CRM problems.

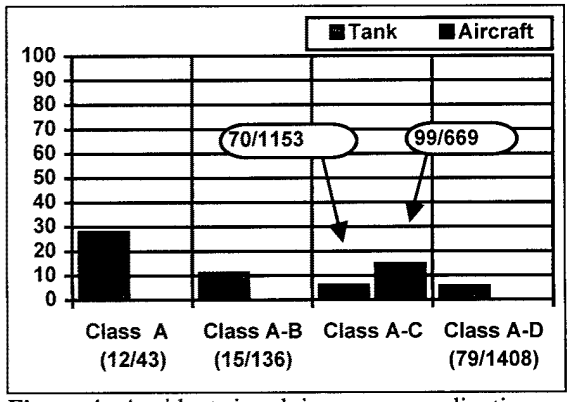


Figure 4. Accidents involving crew coordination as a percentage of total accidents combining classes

An important gap exists in these accident data. None of the USASC accident cases involving crew coordination problems were associated with combat. Combat losses due to enemy fire are not classified as accidents and do not appear in the USASC database; hence, we could not make conclusions regarding CRM in these losses. Also, Army combat losses involving friendly fire have been classified as accidents only since Desert Storm.

The most complete information on fratricide comes from CALL. Boatner and Patterson (1992) report that during Desert Storm, "direct fire vehicular engagements caused 12 of the 15 Army friendly fire incidents" (p. 4). These authors continue,

> Although coalition thermal sights greatly overmatched the Iraqi capability, many misidentification problems still arose. On the unrestricted desert battle field, direct fire lethality far outstripped the gunner's ability to achieve **positive target identification**. Hence, he based his decision to fire largely upon his knowledge of where he and other friendlies were, or should have been with respect to a given target. Thus **situational awareness**, dependent upon planning and control measures, became key to understanding DESERT STORM fratricide incidents. (p. 4, authors' emphasis)

Many fratricides from Desert Storm appear to have resulted because the range of engagement was greater than the range of identification. Other incidents occurred because friendly forces were misidentified as enemy forces. Enhanced CRM alone may not have prevented these accidents, but might have contributed to safety if it had been combined with other hardware and training fixes. The comments of Steinweg (1995) suggest a need for improved crew coordination:

> Combat identification failures and poor situational awareness are the two major reasons for fratricide in the Persian Gulf War. Situational awareness refers to land navigation errors (being in the wrong place) and insufficient coordination between units and individuals as they move about the battlefield. (p. 17)

The findings of the present USASC Database search, augmented by fratricide findings, suggest that some form of CRM training, specifically adapted to the tank environment, is apt to be beneficial in improving tank crew coordination. This improvement could reduce the number of accidents related to poor crew coordination.

Tank Crew Coordination: Current State

Hardware Fixes. Crew communication and coordination can be enhanced with hardware improvements. Whitaker, Peters, and Garinther (1990) demonstrated that degraded speech intelligibility adversely affects mission performance and success. Whitaker (1991) found that navigation and gunnery task performance decreased as intelligibility decreased. By reducing noise and increasing the desired signal, communication and performance could improve.

Based on fratricide experience during Desert Storm, CALL (Winneke, 1995) issued a user's guide for combat identification quick fix devices. These devices include thermal tape combat identification panels, BUDD lights, and Phoenix lights. The BUDD and Phoenix lights both emit near-infrared light and are small; each is powered by a 9-volt battery. The BUDD light pulses every two seconds; the Phoenix light may be used with a variety of light codes. All of these devices are used visually to *positively* identify friendly forces; to work, they must be used as specified (e.g., panels have to be correct size, painted with thermal tape or paint). Overall, these measures were believed to be "marginally effective" (Doton, 1996, p. 11).

New command and control navigation and communication devices are also being developed to increase coordination among tanks. Atwood, Winsch, Sawyer, Ford, and Quinkert (1994) describe the Combat Vehicle Command and Control (CVCC) program, which evaluated new navigation and communication controls and displays in the SIMNET environment. Doton (1996) notes that tank position/navigation information enhancement devices are being implemented on the M1A1 tank. Such new equipment could decrease the fratricide rate by increasing positive identification of targets and augmenting situational awareness.

Training Fixes. Although several efforts address the hardware aspects of crew coordination problems, no complementary, formal training programs designed to target crew coordination were discovered. Smaller-scale information dissemination efforts have been made to correct CRM-related problems such as fratricide. For example, CALL has issued newsletters to help units combat fratricide-related problems (Boatner, 1992; Boatner and Patterson, 1992). An important consideration is that the new hardware fixes might be more effective if they are coupled with training fixes, such as emphasis on situational awareness and total team consciousness.

Potential CRM Training Delivery Methods. The absence of formal team coordination training curriculum within the tank-related training environment is consistent with other literature findings. Andrews, Waag, and Bell (1992) note that generally, more emphasis has been placed on the development of training *delivery* (e.g., hardware and software used to support crew training) rather than training *development* (e.g., planning, analysis, design, and assessment of team training requirements and solutions). This emphasis may be due to a belief that technology-driven hardware is the best primary solution. More importantly, a lack of effective tools for determining team training needs may also contribute to the difficulty in emphasizing training development (Andrews, Waag, and Bell, 1992).

Excellent opportunities for team communications training already exist. Well-instrumented field training exercises are readily available at locations like the National Training Center at Fort Irwin, CA. State-of-the-art, networked simulators are being developed into a Distributed Interactive Simulation (DIS) compatible system such as the Close Combat Tactical Trainer. In addition, the Synthetic Theater of War (STOW) environment with its combined live, virtual, and constructive capability will greatly enhance the ability to train the team in communication and collaboration skills. Also, the Advanced Distributed Simulation architecture projects developed with the High Level Architecture (HLA) protocols will enable training of CRM-related skills between members of the "larger team" located outside the tank. However, there may be significant problems with relying solely on training delivery methods to impart the necessary team skills. Andrews, Waag, and Bell (1992) state,

> Sometimes, there is an implicit assumption that, if we take skilled individuals and put them in a team performance environment, training (learning of new team skills) will automatically occur. Unfortunately, this approach may not produce the desired results.
>
> The 'unstructured' approach of putting trainees into a team performance environment, and then expecting them to automatically learn new skills, is not efficient. Work teams seldom have the luxury of taking enough time away from their operational settings to practice [sufficiently] to gain team skills by discovery alone. The skills should be clearly identified, and then systematic training should be developed and applied. (p. 290)

The point that team skills training must involve more than just combining skilled members of a group together during technical training is further emphasized by Salas, Bowers, and Cannon-Bowers (1995) who state:

> The military has, for some time, relied on the performance of teams for many critical tasks. It was assumed that effective teams would result simply from combining appropriately trained individuals. However, a variety of mishaps involving aviation crews, naval surface warfare teams, and tank crews have demonstrated that effective team performance is not an automatic occurrence. (p. 55)

To fully exploit the STOW environment, and DIS and HLA technologies, CRM training objectives, tests and behavioral checklists are needed.

Possible Application of CRM for Tank Crews

Because of its refinement in the aviation sector, CRM could be nearly an off-the-shelf solution for tank crews. Speaking of the aviation CRM training approach, Huey and Wickens (1993) state,

> Given the conceptual similarities, it would appear that the outcomes of tailoring these training approaches to the tank environment would have a high probability of success, not only in improving transitions from monitoring to action, but also in improving overall team effectiveness. This approach would seem to fit naturally into the types of simulations accomplished using SIMNET. (p. 233)

Promising Transfer of Army CRM Technology. Moreover, the US Army Aviation CRM program was designed to be exportable outside of aviation. The Army Aviation Center reports that "this [CRM] program is not limited to aviation; the procedures are usable in any vehicle" (USAAVNC, 1995). Supporting this statement, negative application of the Army's 13 basic qualities can be seen in a number of tank accidents. For instance, the absence of assertiveness (basic quality #12) and team situation awareness (basic quality #7) in crew coordination is conspicuous in this accident excerpt:

> The driver initiated a right turn as his tank approached the ditch from the north, During this turn, he and the other crew members heard the Tank Commander (TC) command "Go left! Go left! Go left!" The driver stopped his right turn and, seeing a dark area in his driver's night vision sight in the commanded direction, asked the TC, "Are you sure?" The TC responded "[expletive] just turn left" or words to that effect. The driver initiated the left turn and felt the vehicle's left front dip, as though going into a depression. He attempted to turn the vehicle back to the right, but the tank slid into the 15-foot deep ditch as the embankment gave way. The tank overturned and finally came to rest, pinning the TC beneath.

In the following accident record excerpt, the basic qualities of communicating and acknowledging actions

(#8) and providing complete, verified directives (#6) are missing.

> The tank commander knew the "enemy" should be to his right front (northeast) and told his driver to begin looking for a tank trail to the right so they could exit the hard-surface road upon contact with the "enemy." He also told his gunner to be ready to start scanning to the right as soon as they cleared a tree line along their right side. Approximately halfway down the hill, the tank cleared the trees and the TC announced over the vehicle intercom system, "{gunner's name}, traverse right," . . . (PAUSE) . . . "hard right." As the gunner traversed the gun tube right to a position between 1 and 3 o'clock, the driver also responded to the "hard right" command. Thinking the command was directed at him, the driver executed a hard right turn which moved the right track of the tank off the hard surface of the roadway and down a 3-foot drop onto a soft shoulder part of the roadbed. The TC immediately responded with, "No, No, {driver's name}, not you!" The driver quickly moved the T-bar steering controls to a hard left position and accelerated; however, the road shoulder gave way and the tank departed the roadway at approximately 20 MPH. The tank then rolled to the right down a 70-degree slope and came to rest inverted approximately 60 feet to the side and 16 feet below the surface of the road.

In addition to these accidents, crew coordination problems also appeared in several accidents involving turret movement crushing a crewmember. In many of these cases, lack of communication within the crew played a key role. Training of the 13 basic qualities could prove useful in preventing such accidents. Additionally, a variation of the Line/LOS or ACE checklist could be used to behaviorally rate CRM skills in the simulator and STOW environments.

CRM Training Phases. Aviation CRM training programs typically have three major phases: (1) initial indoctrination/awareness, (2) recurrent practice and feedback, and (3) continual reinforcement (FAA, 1995). Similar phases may enhance tank collective training.

Presumably, because the purposes of these phases are general in nature, they could be applied directly to a CRM program for M1A tank crews. Härtel and Härtel (1995) recommended a similar direct transfer of the three phases from flight deck CRM programs to Air Traffic Control (ATC) CRM programs. Essentially, the purpose of each training phase remains the same across training environments (e.g., flight deck, ATC, tank) but the curriculum trained in each phase must address the specific elements unique to each training environment. To illustrate, the flight deck, ATC, and tank CRM programs could all have a similar awareness phase. The purpose of this phase would be the same for all three programs: familiarize students with the basic CRM concepts and aid the understanding of human factors impacts in the operational environment. Beyond this purpose, however, the flight deck, ATC, and tank CRM awareness phases should focus on training *different* CRM concepts that are tailored to the specific operational environments of each.

In the tank environment, the recurrent practice and feedback stage could be facilitated by DIS, HLA, and other advanced technologies. Aviation crews receive CRM training practice in the simulator environment. For instance, crews may "fly" a real-world scenario (that involved CRM problems) and are evaluated using CRM behavioral checklists. Tank crews could also be trained and evaluated in this way, using scripts from actual CRM-related accidents.

Finally, continual reinforcement is necessary. Consider the comments of the FAA (1995):

> Research also suggests that when there is no effective reinforcement of CRM concepts by way of recurrent training, improvements in attitudes observed after initial indoctrination may tend to disappear, and individuals' attitudes may tend to revert to former levels. (p. 3)

Use of tank CRM-related accident scenarios could add realism to recurrent CRM-type training.

Considerations for Adapting CRM for Tanks

Although aviation CRM shows much promise for application in tank crews, there are certain differences between the crew structures and method of functioning. Huey and Wickens (1993, p. 231) list several of the similarities and differences between civil aircrews and tank crews with respect to crew interactions. Among the differences are:

- Tank environment is much less benign
- Tank environment has (necessarily) less face-to-face communications
- In tank warfare, decision making and information processing are less dependent on open communications
- Military rank structure may (positively or negatively) override individual characteristics.

We can learn two major lessons from the experience of applying cockpit CRM to the ATC environment (Koenig, 1995). First, CRM is not a remedy for all tank crew problems, but could be included as one part of a comprehensive training program. Härtel and Härtel (1995) stated, "although we believe that CRM can benefit ATC, it should not be characterized as a panacea. CRM is unlikely to rectify problems caused by deficient basic skills training or inadequate safety standards" (p. 32). The second lesson is that based on differences in crew structure and functioning, ATC CRM had to focus on different issues than cockpit CRM. Likewise, we expect that aviation CRM training

will have to be further tailored for tank team skill training because of key differences. Examples of these differences involve the crew hierarchy and turbulence. Additionally, reflective tank CRM practice may not be appropriate in time-pressured situations.

Crew Hierarchy. In the aircrew, the pilot and copilot are both capable of flying the aircraft, and both can perform similar tasks over the course of a flight. Essentially, these cockpit crewmembers are part of the redundancy required in most aviation systems—they serve as backup systems for each other.

Tank crews differ significantly from aircrews, in that task responsibilities, in addition to rank structure, may determine hierarchy flexibility. Typically, tank crewmembers are assigned very specific roles, including tank commander, driver, loader, and gunner. All crewmembers are subordinate to the tank commander. Because crewmembers have different responsibilities, they may have very different perceptions of the same situation, as well as different capabilities in executing a solution. Keesling (1995) states that "these differences in the ability to balance workload imply that the role of communication within the tank may be different from its role within the cockpit" (p. 7).

Crew Turbulence. Turbulence, the attrition of crewmembers due to reassignment, has received attention both in relation to safety and in relation to performance. Keesling (1995) states that there appears to be an initial familiarization period required for aircrews to operate proficiently as a team (as suggested by accident rate measures). In general, flight crews are together for a very short time, while tank crews may spend 6-12 months together as a team. This team life may impact the nature of the team interaction and the needs for CRM training.

CRM and Time-Pressured Instances. The thoughtful, reflective practice of CRM behaviors probably does not have a place in the stress-filled, time-pressured combat environment. Interestingly, a parallel exists here with the aviation environment. The FAA (1995) notes that during emergency conditions, it is doubtful that the flight crewmembers will reflect on the appropriate CRM behavior to use. However, the FAA also asserts that the routine practice of desirable CRM behaviors under normal circumstances should augment the effective handling of emergencies.

Timely Development of a Tank CRM Program

Although aircrew-oriented CRM would need to be tailored by several important considerations, CRM training appears to be appropriate for tank crews. Analyses of critical incident reports could be reviewed to determine the behaviors involved in tank crew coordination problems. Härtel, Smith, and Prince (1991) performed such an analysis on 216 military aviation mishap reports, finding support for the seven crew coordination skills identified by Prince, Salas, and Franz (1990) (i.e., assertiveness, decision making, adaptability, mission analysis, leadership, situational awareness, and communication). Likewise, a similar analysis of tank mishaps could confirm these findings for the tank environment and be used to expand the role of CRM training for tank crews. The Army is now expanding the infrastructure necessary to train a structured CRM curriculum at its National Training Center and in DIS exercises. The time seems appropriate to begin to develop a tank CRM program based on aircrew lessons learned and tailored to meet the unique needs of the tank crew and commanders. This program could also help to address the problems of information overload on the digital battlefield.

CONCLUSION

Findings from analysis of the USASC database, together with CALL fratricide accounts, suggest that tank crew coordination training may not presently receive adequate emphasis.

An analysis of the USASC database indicated that a significant proportion of non-combat tank accidents (27.9% of Class A) were related to crew coordination. Further, the Desert Storm fratricides were not (at the time) classified as accidents and hence not included in the USASC database. Some of the CALL fratricide incidents may also have been crew coordination-related. The Army has initiated several hardware fixes to improve identification of friendlies, but no broad-based effort to train crew coordination and situational awareness (similar to CRM principles) could be found. The Army now has outstanding facilities like the National Training Center in which to train CRM-related skills during exercises. In addition, DIS and HLA technologies and STOW environments offer the opportunity to develop a structured CRM-related curriculum. This improved curriculum could provide practice in CRM skills through use of scenarios based on actual accidents and fratricides. Behavioral marker-style evaluation checklists used in a structured CRM-type curriculum tailored for tank crews can offer the Army excellent training in this important area. Advanced training technology, combined with a strong CRM-style curriculum, has a high possibility of reducing crew coordination and situational awareness-type accidents, as well as fratricides.

The Army may also benefit from emphasizing the crew coordination behaviors that are already inherent in their

leadership courses, standard communications procedures, and standard operating procedures by using CRM-related accident scenarios.

ACKNOWLEDGMENTS

The authors thank Dr. Eduardo Salas and Dr. Carolyn Prince of the US Naval Air Warfare Center in Orlando, FL for providing applicable research documents; MSgt Dennis Curran at USASC and Ms. Donna Egner of SURVIAC for searching and summarizing pertinent accident records; Mr. Rick Bogdan of CALL and Mr. Richard Zigler of ARL's Survivability/ Lethality/ Analysis Directorate for valuable fratricide insights; and Mr. Mark Neumeier for providing extensive CRM background information. Thanks also go to Mr. John Wilhelm and Mr. Bob Vidensik for information on CRM programs, and to Mr. Dennis Ricketson and Ms. Charise Lyle of USASC for insight on tank and aviation accidents. Finally, we thank Dr. Aaron W. Schopper (CSERIAC Chief Scientist) for comments on the scope and review of the content of this report.

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