Technical Report 958

Assessment of Workload in a Field Environment: Implications for Some Unresolved Workload Issues

Michelle R. Sams and Richard E. Christ
U.S. Army Research Institute

July 1992

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for the Behavioral and Social Sciences

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This report describes a study that evaluated the impact on crew workload of adding the Stingray system to the Bradley Fighting Vehicle (BFV). Four BFV crews participated in force-on-force offensive and defensive missions in a baseline BFV (without Stingray) and a BFV with Stingray. Workload was assessed through operator ratings, post-mission debriefs, video and audio recordings, and an end-of-test questionnaire. Results indicated that workload was dependent on mission type (offensive or defensive) and mode of operation (baseline, Stingray-automatic, Stingray-semiautomatic, and Stingray-manual). Crew strategies to reduce workload included reallocation of some BFV commander tasks to the BFV gunner and driver. A significant negative relationship between workload and force effectiveness was demonstrated (i.e., increases in crew workload were associated with decreases in force effectiveness). The utility of the workload measurement techniques employed in the study is discussed in terms of the practical and procedural significance of the study results.

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Assessment of Workload in a Field Environment: Implications for Some Unresolved Workload Issues

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) supports the Army with research and development on manpower, personnel, training, and human performance issues. One concern that underlies all of these issues is the mental workload imposed on and experienced by the operators of newly emerging, high-technology systems and the impact of that workload on operator and system performance. The Fort Bliss Field Unit is conducting exploratory development research for establishment of an operator workload assessment program for the U.S. Army.

This technical report documents the ninth field study of operator workload conducted by the Fort Bliss Field Unit. The Stingray system, which is the focus of the present study, is the fifth system studied in the Fort Bliss workload research program. This particular study was conducted at the request of the Air Defense Artillery Test Directorate of the U.S. Army Test and Experimentation Command. The results of the field study contributed significantly to key goals and objectives of the system proponents, the system developers, and the testing agency. Further, the workload data and other information obtained in the study produced several unexpected findings. For example, system operators changed a number of standard operating procedures in response to the workload they experienced. Findings such as these have important implications for the continuing development and deployment of the Stingray system.

In addition, the present study makes important contributions to the technology base. The results of this effort have added substantially to the knowledge base for a number of important methodological issues in the areas of workload assessment and management and to the U.S. Army's understanding of the impact of operator workload on system performance and force effectiveness. Perhaps most important, the results of this study confirm that the experiences reported by a system operator are both reliable and unique sources of information for system developers.

EDGAR M. JOHNSON
Technical Director

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The authors wish to thank the Air Defense Artillery Test Directorate of the U.S. Army Test and Experimentation Command at Fort Bliss, Texas, for the opportunity to conduct research of general interest while addressing the Concept Evaluation Program (CEP) requirement to evaluate the impact of Stingray operations on a Bradley Fighting Vehicle (BFV) crew. In particular, we would like to express our gratitude to the CEP Test Officer, Captain William S. Williford, for allowing our early input and modifications to the test design and conduct, thereby providing the foundation for our research.

The primary author would like to thank Don Johnson, Test Analyst, for help in learning the ropes in operational field testing and Staff Sergeant Edward Cunningham for help in gathering the workload data from the BFV crews. Thanks also to Staff Sergeant Richard Miller and Sergeant Roland Pena of Fort Benning, Georgia, who provided Stingray training assistance to the troops and to the workload analyst. Special appreciation is given to two members of the Data Analysis Group, Richard Hiss and Ron Murphy, who provided vigorous input to all aspects of the CEP test design, conduct, and analyses. Recognition is also given to a colleague, Alvah C. Bittner, Jr., who provided sound advice on certain aspects of the statistical analyses of the workload data.

The Stingray CEP and this technical report would not have been a success were it not for the cooperation of the troops from the 1st Squadron, 3rd Armored Cavalry Regiment, Fort Bliss, Texas. Acknowledgment is given to the A Troop Commander, Captain Morris, the Stingray Platoon Leader, First Lieutenant William Uemora, and the Stingray Platoon Sergeant, Staff Sergeant Robert Sechrist. The four BFV crews who participated in special training and operated the Stingray system deserve special accolades. They exhibited a true desire to give 100% to the evaluation of the Stingray system and provided the feedback and insights necessary to compose a thorough picture of the workload they experienced. So, a very special thanks to the following dedicated Stingray-trained BFV crew members, the Bradley commanders (BC), gunners (GU), and drivers (DR):

<u>Crew 1</u>
BC: SSG Terry Thacker
GU: SPC Daniel Dollahite
DR: PVC Brian Shupe

<u>Crew 2</u>
BC: SGT Mahlon Stuckley
GU: SPC Benjamin Smith
DR: PVT Ruben Hernandez

<u>Crew 3</u>
BC: SGT Dana Charette
GU: CPL Jose Moreno
DR: PVT Herbert Patterson

<u>Crew 4</u>
BC: SGT Exequiel Chacon
GU: PFC Dudley Greene
DR: PVT Stuart Bailey

ASSESSMENT OF WORKLOAD IN A FIELD ENVIRONMENT: IMPLICATIONS FOR SOME UNRESOLVED WORKLOAD ISSUES

EXECUTIVE SUMMARY

Requirement:

This report describes a study that evaluated the impact on crew workload of adding the Stingray system to the Bradley Fighting Vehicle (BFV). It offers insight into the assessment and interpretation of operator workload in field environments.

Procedure:

Four BFV crews participated in force-on-force offensive and defensive missions in a baseline BFV (without Stingray) and a BFV with Stingray. Workload was assessed through operator ratings, post-mission debriefs, video and audio recordings, and an end-of-test questionnaire. System performance was assessed using the force effectiveness ratio.

Findings:

Results indicated that workload is dependent on mission type (offensive or defensive) and mode of operation (baseline, Stingray-automatic, Stingray-semiautomatic, or Stingray-manual). Crew strategies to manage workload included reallocation of some of the Bradley commander tasks to the BFV gunner and driver. A significant negative relationship was established between workload and force effectiveness (i.e., increases in crew workload were associated with decreases in force effectiveness). The utility of the workload measurement techniques employed in the study is discussed in terms of the practical and procedural significance of the study results.

Utilization of Findings:

The findings of this Stingray workload assessment are included in the Concept Evaluation Program (CEP) final test report. Based on information gained through the Stingray workload assessment, important revisions were incorporated into the Stingray System MANPRINT Management Plan. Two conference papers based on this study were published. "Assessment of Workload in a Field Environment" was published in the Proceedings of

the 34th Annual Meeting of the Human Factors Society, and "General Issues of Operator Workload" was published in the Proceedings of the 12th Biennial Psychology in the Department of Defense Symposium. This Stingray workload evaluation study serves as a model for Army programs that must address operator workload issues and concerns.

ASSESSMENT OF WORKLOAD IN A FIELD ENVIRONMENT: IMPLICATIONS FOR SOME UNRESOLVED WORKLOAD ISSUES

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INTRODUCTION

Purpose of This Report

The research effort described and discussed in this report had two major objectives: (a) to provide information of immediate practical value to the developers and proponents of an emerging weapon system, and (b) to expand and enhance the Army's capability to assess and understand the impact of operator workload.

This introductory section is used to provide background information concerning the problem created when new Army systems impose increased demands on soldiers for mental skills, the concept and measurement of operator workload, and the operator workload research program of the Fort Bliss Field Unit of the U.S. Army Research Institute (ARI). This section also contains a description of an operational field test of the Stingray system, a brief discussion of several key operator workload issues, and a list of specific research questions this effort was to address.

The methods employed during the research effort and the quantifiable results obtained are described in two subsequent sections. An expanded discussion of the results and their implications for both the specific weapon system under study and the more general operator workload issues are contained in a separate section of the report. The conclusions that can be drawn from this research effort are in the final section of the report; it is argued that the results of this research have important implications for future operator workload assessment and research programs.

Background

Problem. Projected manpower declines coupled with increases in personnel costs and battlefield sophistication has prompted an increased reliance on high technology equipment in new Army systems. As technology has changed, so has the role of the operator of this equipment. Tasks assigned to the operator have shifted from those that primarily require physical exertion and motor coordination to those that increasingly impose perceptual and cognitive demands.

While technological advancements are designed to increase system capability, it is critical to ensure that they do not also cause an unanticipated increase in the requirement for operator mental skills. Task demands greater than an operator's capacity to respond may result in undesirable consequences, such as a degradation in mission performance or a compromise in system safety.

Definition and assessment of operator workload. The concept of operator workload is generally defined in terms of an interaction between the demands imposed upon the operator and the capabilities of the operator to successfully respond to those demands. The conceptual foundations of operator workload, to include the relationship between workload and performance, have been discussed extensively in numerous recent publications (e.g., Gopher & Donchin, 1986; Lysaght et al., 1989). Likewise, there have been numerous reviews of techniques available to assess operator workload (e.g., Lysaght et al., 1989; O'Donnell & Eggemeier, 1986; Wierwille & Williges, 1980).

While there has been considerable attention given to operator workload and its assessment, most operator workload research has occurred in academic laboratory settings. The limited applied research has been principally associated with the operation of aviation systems. Consequently, there remain many questions concerning the application of operator workload to the design and development of new systems. In addition, there is a void in specific guidance concerning how best to conduct an operator workload assessment and analysis program for a given system.

The ARI operator workload (OWL) program. In response to the need for useful guidance in the assessment of operator workload, the ARI Field Unit at Fort Bliss, Texas, launched a multi-year research effort called the Operator Workload (OWL) Program. The researchers who conducted this program defined the needs of the Army (Hill et al., 1987), critically reviewed and evaluated the operator workload concept and workload assessment techniques (Lysaght et al., 1989), and conducted field assessments of operator workload for the following Army systems:

- Aquila remotely piloted vehicle (RPV) (Byers, Bittner, Hill, Zaklad, & Christ, 1988),
- Line-of-sight forward heavy (LOS-F-H) component of the Forward Area Air Defense System (FAADS) (Bittner, Byers, Hill, Zaklad, & Christ, 1989; Hill, Byers, Zaklad, Bittner, & Christ, 1988; Hill, Byers, Zaklad, & Christ, 1989a, 1989b; Hill, Zaklad, Bittner, Byers, & Christ, 1988), and

- UH-60 Black Hawk helicopter (Iavecchia, Linton, Bittner, & Byers, 1989).

The results of these efforts in the ARI OWL program were the basis for the development and publication of two research products:

- A pamphlet for Army managers describes the need and some procedures for incorporating operator workload issues and concerns into the Army materiel acquisition process (Christ, Bulger, Hill, & Zaklad, 1990), and

- A computer-based tool, the operator workload knowledge-based expert system tool (OWLKNEST), and its user's manual, the Handbook for Operating the OWLKNEST Technology (HOOT), provide guidance for selecting the workload assessment techniques most appropriate for any specific situation (Harris, Hill, Lysaght, & Christ, 1991).

The results of the OWL Program were used to identify gaps in our knowledge and understanding of operator workload concepts and assessment techniques (Christ, Zaklad, Bittner, Hill, & Linton, 1989; Sams & Christ, 1990). Additional research is required to fill these knowledge gaps.

The Stingray Concept Evaluation Program (CEP)

In September, 1989, the Air Defense Artillery Board of the U.S. Army Test and Experimentation Command (TEXCOM) formally requested that the Fort Bliss Field Unit of ARI support an operational field test of a proposed improvement to the Bradley fighting vehicle (BFV). This product improvement consisted of adding a new weapon system called Stingray to the weapon system ensemble already available to the BFV crew. The field test was the basis for a concept evaluation program (CEP) for the Stingray system. The major objectives of the field test were to (a) evaluate the impact on force effectiveness of adding Stingray to one of four BFVs in a mechanized infantry platoon and (b) determine any impact of Stingray operations on the workload of the Bradley commander (BC).

The invitation to participate in the field test of the Stingray system presented an opportunity to satisfy two major missions of the ARI field unit. It permitted the field unit to fulfill its mission to generally support U.S. Army initiatives; in this case, to address the major objectives of the Stingray CEP. It also permitted the field unit to pursue its mission to conduct behavioral science research; in this case, to continue the research effort begun under the ARI OWL research program.

Brief description of the Stingray system. Stingray is a laser system designed to augment the more conventional weapons of mechanized infantry units. The Stingray system will detect and temporarily deprive the opposing force of the use of their optical and electro-optical devices. Therefore, the Stingray system is used principally as a countermeasure system.

The Stingray system has three modes of operation, each requiring different types and amounts of action from the BC. Once the Stingray system is activated in the automatic mode, there are no additional actions required of the BC; the system will search for, detect, and countermeasure optical and electro-optical capabilities of the opposing force. In the semiautomatic mode, Stingray automatically scans for targets and, if any are detected, presents them for 10 seconds on a visual display unit (VDU) inside the BFV turret for evaluation by the BC. If the BC decides that the target is a threat, the BC countermeasures it by centering the VDU cross hairs on the target and depressing a trigger switch on the turret joystick. The manual mode of Stingray requires the BC to control the search pattern with the joystick, detect and evaluate targets shown in the visual display, and countermeasure threats with a trigger pull.

For any of its three modes of operation, Stingray signals a target detection with an auditory alarm either through speakers in the turret or through a headset incorporated into the Combat Vehicle Crewmember (CVC) helmet. Once Stingray is used to countermeasure an optical or electro-optical capability of the opposing force, target position information (i.e., range and azimuth) is displayed to both the BC and gunner as an aid for target engagement with conventional BFV weapons (i.e., the TOW missile launcher or the 25-mm gun).

Operator Workload Research Issues and the Opportunities Presented in the Stingray CEP

Participation in the Stingray CEP permitted research to be conducted that addresses several unresolved issues in the assessment and interpretation of operator workload. These issues are briefly described in the succeeding paragraphs.

"Crew" workload. A key CEP test objective was to determine any impact of Stingray operations on the workload of a single member of the BFV crew, the BC. However, after studying the functions of Stingray and the required tasks of the Bradley crew, it was concluded that the workload of the entire crew could and should be evaluated. This expansion of the test objective is an important change from most previous operator workload studies.

In a typical study, the impact of workload is examined for only a single system operator. However, as noted by Hart (1989b), "The effects of crew coordination and shared task performance on workload are virtually unknown. They are rarely studied in the laboratory, and although they certainly affect the workload of individual crew members in operational situations, they have not been studied systematically there either" (p.22).

The Stingray CEP permitted detailed workload analyses to be performed for the BC and gunner, and a more cursory analysis to be performed for the driver. The effects of workload on the entire crew could therefore be examined under various conditions in a baseline BFV (i.e., a BFV without Stingray capabilities) or in the Stingray BFV in each of its three modes of operation.

Workload management strategies. Participation in the Stingray CEP provided an opportunity to identify and examine consequences of any workload management strategies employed by BFV crew members. Operator strategies play an important role when examining the relationship among objective task demands, experienced workload, and system performance. However, previous research has virtually ignored the role of this important variable (Hart, 1989a).

When faced with high task demands, operators may adopt any number of strategies in an attempt to maintain an acceptable level of performance. For individual operators, required tasks may be rescheduled, and tasks which are not absolutely required may be shed and simply not performed. For crew operations, as occur in the BFV, tasks may be reallocated among crew members in an effort to redistribute the workload. These dynamic responses of system operators have important implications for new systems in terms of equipment design, task allocation, and training.

Workload and performance. There is much debate among researchers about the "validity" of operator workload assessment techniques as measured by the relationship between operator workload and performance (Sams & Christ, 1990). For example, Hart (1989b) contends that there is a difference between measuring task performance and measuring the amount of effort expended to perform the task. Operators may report high workload (e.g., by means of rating scales) and still be able to exert the extra effort required to achieve desired performance levels. However, under some conditions, such as after a period of sustained operations, the operator may not be able to call up additional effort and performance may be degraded.

In contrast, other researchers posit that objective performance measures for the operator and system are more accurate indicators of the effects of workload than the subjective experience of the operator (Seven, 1989). These measures might include crew performance time and error, as well as the resulting system performance. Wickens (1989) states that the "ultimate design criterion should be satisfactory performance rather than adequate subjective opinion" (p. 271).

In the Stingray CEP, both "subjective" measures of workload (i.e., operator ratings) and "objective" measures (i.e., crew and system performance measures) were to be obtained. The association between these two types of measures could then be analyzed. Aside from the theoretical research interest, a demonstrated relationship between the workload experienced by the crew members and the performance of the system would be of significant value to the Stingray operational test findings.

Prospective and retrospective rating techniques. Two issues associated with using operator workload ratings relate to the timing of the measurements. On the one hand, rating techniques can be used "prospectively" to predict the amount of workload that will be experienced by the operator of either a future system or an existing system that is to be modified or operated in some innovative manner. On the other hand, rating techniques can be used "retrospectively" to report the amount of workload that was experienced by the operator of a system during an earlier period of time. Previous studies in the ARI OWL program examined both of these issues but were unable to firmly establish the validity of either the prospective or retrospective rating techniques used.

Hill, Byers, Zaklad, Bittner, and Christ (1988) showed that operators of a prototype system can prospectively rate the workload that would be associated with system configurations and with system employment procedures they had not yet experienced. Bittner, Byers, Hill, Zaklad, and Christ (1989) found no difference in the prospective workload ratings of experienced operators and subject matter experts who had no actual experience operating the system under study. Both groups were to rate the workload that would be experienced by system operators during proposed but untried generic mission scenarios.

In most operational tests of emerging systems, workload ratings are obtained retrospectively, most typically within a few minutes or hours after completing system operations. For example, Hill, Byers, Zaklad, and Christ (1989b) had operators of a mobile air defense system rate workload within one hour after the completion of four-hour missions. However, in other field studies, the first opportunity to assess operator experiences may not occur until after some longer period of time has passed. For example, Hill, Zaklad, Bittner, Byers, and Christ (1988) could not gain access to the operators of the same mobile air defense system until ten weeks after the field test was completed. In both of these retrospective workload rating studies, system operators rated the workload they had previously experienced after viewing video tapes of their earlier performance. However, neither of these studies was able to establish that retrospective ratings were valid indicators of the workload experienced when the task or mission was actually being performed.

The ideal method for validating either prospective or retrospective workload ratings is to compare them with real-time workload ratings obtained while or immediately after the operator performs the tasks or the mission of interest. The Stingray CEP provided a unique opportunity to gather workload ratings from one set of subjects prospectively (at the conclusion of system-specific training but prior to the test missions), real-time (immediately following each test mission), and retrospectively (at the conclusion of all test missions). The correspondence between these measures will provide some information about the validity of rating scales as prospective and retrospective workload assessment techniques.

Alternative workload assessment techniques. The results obtained during the ARI OWL program have two important implications for how to successfully measure workload in field settings (see Zaklad, Harris, Iavecchia, Christ, & Sams, 1990). First and foremost, the workload assessment technique must be non-intrusive since any extra tasks imposed upon a system operator for the purpose of assessing workload could well interfere with the operator capability to perform primary mission-essential tasks. All experimental variables, conditions, and procedures which define the workload assessment effort must dovetail with the objectives, constraints, and schedule of the field test. Secondly, since there are so many factors varying concurrently in a field setting and generally insufficient resources to do all that is desirable, it is necessary to tap into multiple sources of information and to utilize a battery of alternative workload assessment techniques and procedures. In these regards, the actual assessment techniques employed must be robust and must collectively yield the maximum amount of information for a given level of effort.

The techniques available in the Stingray test to assess and interpret workload included operator ratings of workload, post-mission debriefings of system operators, visual and auditory recordings of operator and system performance, and an end-of-test questionnaire. One research objective was to evaluate the usability and usefulness of these alternative techniques.

Of particular interest was the evaluation of absolute and relative measurement techniques when each is used prospectively and retrospectively to estimate real-time measures of workload. Absolute measurement techniques require an operator to estimate the magnitude of workload associated with each task or test condition independently of any other condition. Relative measurement techniques require an operator to directly compare the workload associated with the different tasks or conditions of interest.

The absolute measurement technique chosen for this study was the Task Load Index (TLX) workload rating scale (NASA-Ames Research Center, 1986). This particular rating scale was selected over other frequently used workload rating scales based on studies demonstrating its factor validity and user acceptance, and its utility as both a prospective and retrospective rating technique (Byers, Bittner, Hill, Zaklad, & Christ, 1988; Hill, Zaklad, Bittner, Byers, & Christ, 1988). The Subjective Workload Dominance (SWORD) rating scale was selected as the relative measurement technique since it has been shown to be a sensitive prospective and retrospective measure of workload (Vidulich, Ward, & Schuren, in press). The use of SWORD in the present study was also desirable since it has previously been contrasted with TLX (Vidulich & Tsang 1987, 1986), but has not been previously used in an Army field test.

The remaining measurement techniques used during the Stingray CEP were principally selected to provide information that would be essential for interpreting the more quantitative data that would be available from the rating scales. Interviews and questionnaires, in particular, are frequently used in field test environments and are valuable tools for obtaining the evaluations and opinions of test participants (Enderwick, 1987; Meister, 1985, 1986).

Specific Workload Research Questions for the Stingray CEP

The following questions guided this research effort:

1. What impact does Stingray have on the workload experienced by the BC and other BFV crew members as they perform mission-essential tasks?

2. What workload management strategies, if any, are employed by the crew of the Stingray-augmented BFV?

3. What is the relationship between real-time operator workload ratings and both crew and system performance?

4. What is the correlation between both prospective and retrospective operator workload ratings and real-time operator workload ratings?

5. How useful are the various workload assessment techniques employed in the Stingray CEP for assessing and interpreting operator workload and performance?

METHOD

Participants, Force Composition, and Stingray Training

Elements of the 1st Squadron of the 3rd Armored Cavalry Regiment (ACR) served as players in the Stingray CEP. A platoon comprised of four squads (i.e., four BFVs and their crews) served as the Stingray test platoon. Other elements drawn from the 1st Squadron served as supporting players of the Blue force or as surrogates of threat systems of the Red force. The Blue force used accepted U.S. Army mechanized infantry tactics. The Red force was trained to use accepted Soviet mechanized infantry tactics.

The Blue defensive force consisted of only a mechanized infantry platoon (i.e., the Stingray test platoon). The Red offensive force consisted of a mechanized infantry company (using nine BFVs as surrogates for the Soviet armored infantry vehicle, BMP) supported by Soviet tanks (using four M-1 tanks as surrogates for Soviet main battle tanks).

The Blue offensive force consisted of three M-1 tanks and nine BFVs. Four of the BFVs were those assigned to the Stingray test platoon. The Red defensive force consisted of a mechanized infantry platoon (using three BFVs as BMP surrogates) supported by a Soviet tank (using one M-1 tank as a surrogate for a Soviet tank).

Each BFV assigned to the Stingray test platoon had a three-man crew. All test platoon crew members were qualified as military occupational specialty (MOS) 19D cavalry scouts. The duty positions and ranks of the three BFV crew members were: Bradley commander (BC), either a staff sergeant (E6) or a sergeant (E5); gunner, a specialist or corporal (E4) or a private first class (E3); and driver, a private (E2).

Prior to the start of the test, the four Stingray test crews received classroom and field training on Stingray operations and maintenance from the system contractor. The Stingray platoon leader and platoon sergeant (who were not assigned to one of the four test crews), as well as the test analysts and data collectors, also participated in Stingray training.

CEP Test Plan

The CEP test plan called for a series of free-play offensive and defensive force-on-force missions conducted under both daylight and night conditions. During each mission, the Blue force was either in a baseline condition or in a Stingray-augmented condition. During Stingray missions, the Stingray system was operated in one of its three different modes (i.e., automatic, semiautomatic, or manual). Consequently, the test design could be represented as a 2 X 2 X 4 factorial experiment comprised of: (a) day or night operations; (b) offensive or defensive missions; and (c) baseline, Stingray-automatic, Stingray-semiautomatic or Stingray-manual conditions.

Two BFVs were designated as test vehicles and were fitted with special instrumentation (e.g., video and audio recording devices). One of these BFVs was equipped with the Stingray system to be used in Stingray missions. The second BFV was used in the baseline missions for control purposes. Hence, for each mission, three of the test crews operated their usual BFVs and one crew operated either the Stingray BFV or the designated baseline BFV. The four test crews rotated through the Stingray and baseline BFVs. Each test crew was to participate at least once in each of the 16 test conditions.

Measures of System and Crew Performance and Effectiveness

Various dependent measures were to be used to determine any difference in Blue force performance and effectiveness between the baseline and the Stingray-augmented mission conditions. Since Stingray is designed to protect the friendly force from fires directed by enemy electro-optical sensing and aiming devices, a measure of Stingray's effectiveness is the force effectiveness ratio (FER). The FER is the proportion of enemy systems "killed" divided by the proportion of friendly systems killed during a mission. High FER values indicate that proportionally fewer friendly systems are destroyed than enemy systems.

Alternately, FER is defined as:

$$\text{FER} = \frac{\text{LER}}{\text{IFR}},$$

where,

$$\text{Loss Exchange Ratio (LER)} = \frac{\text{total no. of enemy forces killed}}{\text{total no. of friendly forces killed}}, \text{ and}$$

$$\text{Initial Force Ratio (IFR)} = \frac{\text{initial total no. of enemy systems}}{\text{initial total no. of friendly systems}}.$$

Initial numbers of systems for the two opposing forces were predetermined for each test mission. The numbers of systems killed for each of the two opposing forces were determined from data obtained from Multiple Integrated Laser Engagement System (MILES) instrumentation on each vehicle.

Crew performance measures which were to be used included time and error measurements for target engagement procedures that are outlined in the Bradley Fighting Vehicle Crew Drills (Training Circular 7-8, 1985). For example, the time from target detection to engagement can be obtained from target handoff procedures between the BC and gunner. These performance data were to be derived from video and audio tapes of crew actions during Stingray and baseline test missions.

Workload Assessment Instruments and Methods

During all missions, data were collected to determine any impact of Stingray on the capability of the BFV crew to perform their required tasks. The techniques used to obtain these data included operator workload ratings, post-mission debriefings, video and audio recordings, and an end-of-test questionnaire.

Task Load Index (TLX) technique. The TLX technique for assessing workload was developed by the NASA-Ames Research Center (1986). Ratings of workload using the TLX are obtained on a scale from 0 to 100 (low to high workload) for each of the six workload rating dimensions which comprise the TLX: (a) mental demand, (b) physical demand, (c) temporal demand, (d) perception of performance, (e) effort, and (f) frustration. Information on the TLX technique is presented in Appendix A-1.

The TLX was used in this study to obtain absolute judgments of workload from the BC and gunner of the baseline or Stingray-augmented BFV crew. The procedure for obtaining TLX measures is designed to account for differences among soldiers in their perception of workload for the tasks to be rated. A weighting procedure requires each BC and gunner to designate the more relevant dimension of workload from all possible pairs of the six TLX dimensions (a total of 15 pairwise comparisons). These paired comparisons were obtained for target acquisition tasks at the conclusion of Stingray training. The proportion of times each workload dimension was judged to be more relevant than the other dimensions was used to weight the TLX workload ratings obtained during the CEP test. A unique weighting scale was thus developed for each crew member and used in the analysis of the TLX workload data.

There are many Bradley crew tasks and only certain tasks were selected for workload ratings. With assistance from subject matter experts, the selection of tasks was based on their relevance to test mission scenarios and the employment of the Stingray system. Six tasks in the target acquisition process described in the Bradley Fighting Vehicle Gunnery Manual (Field Manual 23-1, 1987) were selected for TLX workload ratings by the BC and gunner. These were:

1. Search (look for targets),
2. Detection (discovery of targets),
3. Location (determine target position),
4. Identification (recognize target type),
5. Classification (prioritize targets), and
6. Target handoff (coordination between the BC and gunner for target engagement with conventional BFV turret weapons).

Subjective Workload Dominance (SWORD) technique. The SWORD technique for assessing workload was developed by Vidulich (1989). It is based on the analytical hierarchy process (AHP) developed by Saaty (1980). The AHP was initially applied to the assessment of workload by Lidderdale (1987). SWORD provides a method to extract expert judgments about workload for tasks in relation to other tasks or to evaluate alternative system designs. Information on the SWORD technique used in this study is presented in Appendix A-2.

The SWORD technique was used in this study to elicit relative judgments about workload for each pairwise combination of the baseline and three Stingray modes of operation. The six combinations of these modes of operation were each to be examined for tasks as they occurred in each combination of mission type (offensive or defensive) and time of day (day or night). The BCs and gunners were to indicate whether workload for a particular task and mission condition was equal for two contrasting modes of operation or whether it was higher for one of the modes of operation. If workload was judged to be higher for one mode of operation, the rater was to indicate how much higher on an 8-point scale. For example, a crew member could indicate that the workload associated with the task of searching for targets during daytime offensive missions was equal for the Stingray-semiautomatic and baseline modes of operation, or that workload was moderately higher (with a value of, say, 4) for the Stingray-semiautomatic mode of operation than for the baseline mode of operation.

The SWORD technique was used only to obtain prospective and retrospective ratings of workload. In both cases, the same six target acquisition tasks that were selected for TLX ratings were also selected for SWORD workload ratings. In addition, to these six target acquisition tasks three additional tasks were selected for retrospective ratings using the SWORD technique. The additional three tasks were:

1. Preventive maintenance, checks, and services (PMCS),
2. Communications (i.e., monitoring and inputting information into radio nets), and
3. Land navigation.

Post-mission debriefs. Post-mission interviews with the BC and gunner of the Stingray or baseline BFV were conducted by the workload analyst. Comments were solicited about workload experienced and workload strategies employed, task performance and task performance strategies, system and operator interface design, and issues related to safety and health hazards. Information was also solicited from other crews to elucidate Blue and Red Force tactics and performance.

Video and audio recordings. Video cameras and audio equipment were installed in the Stingray and baseline vehicle to record BC and gunner actions and procedures during all missions. The recordings were reviewed to derive time and error measurements of crew tasks. These measures of crew performance were to be related to workload ratings and system performance measures. The recordings were also used to gain insights about factors affecting crew workload and performance.

End-of-test questionnaire. A questionnaire was developed based on the Stingray CEP test issues, insights acquired during the conduct of the CEP, and various other concerns. The purpose of the questionnaire was to elicit crew comments based on their experience with Stingray in the various mission conditions. Questionnaire topics included task performance and workload, safety, training, Blue and Red force performance and tactics, and general issues about Stingray. A copy of the questionnaire is presented in Appendix A-3.

Test Procedure for Collecting Workload Assessment Data

The Stingray CEP was conducted at White Sands Missile Range, New Mexico, from January 8 through March 12, 1990. At the beginning of the evaluation program, the four BFV crews received four days of classroom training and two days of practical exercises on Stingray operations. At the conclusion of this training, the concept of workload and workload measurement techniques were discussed with the test platoon leader, platoon sergeant, and crews (BCs, gunners, and drivers). Prospective TLX and SWORD workload ratings of the designated target acquisition tasks were obtained from the BCs and gunners. These ratings were collected to evaluate the utility of these instruments for predicting the workload that the BCs and gunners would experience in test missions.

The four crews then participated in 14 force-on-force pilot study missions. Each crew operated Stingray in at least two of its three modes during either a defensive or offensive mission. The pilot missions were conducted primarily to permit a thorough evaluation and fine-tuning of the methods and procedures to be used by test players and field test administrators. The TLX workload rating scales and post-mission debriefs were administered to the designated BC and gunner following each pilot mission. This was done to refine the instruments used by the analyst and to familiarize the crews with the data collection procedures. The pilot mission workload ratings were not used in the analyses.

Following the pilot missions, test missions "for the record" were conducted. In rotation throughout the test, one of the four trained crews was designated to operate the baseline or Stingray vehicle. Immediately after each mission, real-time TLX workload ratings for the six target acquisition tasks were obtained from the BC and gunner of the designated crew. The post-mission interviews (debriefs) with these crew members followed completion of the workload rating scales. Video and audio tapes of the BC and gunner from the designated crew were also recorded during each mission to obtain operator performance data.

On the day following the last test mission, retrospective TLX and SWORD workload instruments were administered to the BCs and gunners of the four BFV crews. The six target acquisition tasks were retrospectively rated using both instruments; three additional tasks were retrospectively rated using only the SWORD instrument. The four crews (including drivers), the platoon sergeant, and platoon leader also completed the end-of-test questionnaire. In addition, the troop commander completed an abbreviated version of the questionnaire primarily covering tactics, safety, and general Stingray issues. Information obtained from the debriefs, tape recordings, and questionnaires was used to aid in interpreting the workload ratings.

RESULTS

Summary of Test Conditions and Constraints

Following the completion of the Stingray training and the 14 pilot test missions, 50 "record" test missions were run. Due to requirements imposed on the conduct of the test and the realities of field testing, not all missions were analyzable and a completely counterbalanced design was not obtained. After the first night test mission, the remaining scheduled night missions were canceled because of safety problems associated with wearing laser protective lens and navigating on unfamiliar terrain. Two other missions were aborted for various reasons before they could be completed.

As a result, the data from only 47 record test missions were subjected to any type of analysis. Of these, real-time TLX workload ratings were obtained and analyzed for only 41 missions. All crews participated at least once in every test condition, except for two crews who did not operate Stingray in the manual mode for a offensive mission. The final distribution of test conditions over the four test crews and the order in which these conditions were administered is presented in a matrix in Appendix Table B-1. There is no evidence to suggest any systematic bias occurred while rotating the four test crews through the eight test conditions.

Real-Time TLX Workload Ratings

The TLX ratings reflect absolute judgments about the magnitude of workload on a numerical scale from 0 to 100. Real-time TLX workload ratings (i.e., those ratings collected at the conclusion of each record mission) were subjected to a mixed factorial analysis of variance, with a between-subjects factor of crew position (BC or gunner) and within-subjects factors of mission type (offensive or defensive), mode of operation (baseline, Stingray-automatic, Stingray-semiautomatic, or Stingray-manual), and task (six target acquisition tasks). Since there were unequal numbers of observations for the different combinations of test conditions, the general linear model procedure of the SAS software was used for this analysis (see SAS User's Guide, 1985). This analysis of variance show that the only significant source of variance was due to the interaction of mission type and mode of operation, $\underline{F}(3,17) = 3.20$, $\underline{p} = 0.05$. (The summary of this analysis of variance is given in Appendix Table B-2).

Figure 1 shows mean real-time TLX ratings for mission type and mode of operation. The data shown in the figure were obtained by averaging across crews, crew positions, and target acquisition tasks. As shown in Figure 1, crew members experience the highest level of workload for the Stingray-manual mode of operation during offensive missions. They report the lowest levels of workload for the automatic mode of Stingray operations during either offensive or defensive missions. Ratings of workload for the remaining five test conditions were at about the same intermediate level. As will be discussed below, this significant interaction effect is particularly important in terms of other information gained from the crews and from the analysis of force effectiveness.

While no significant differences were found for target acquisition tasks or for crew positions, the trends demonstrated in Figure 1 for the effect of mission type and mode of operation are evident also across all levels of both of these two factors (see Appendix Tables B-3 and B-4). In general, for both BCs and gunners and for all six target acquisition tasks, workload ratings were lowest for the automated mode of operations and highest for manual operations during offensive missions.

Finally, the real-time TLX ratings were also examined for any differential contribution of the six TLX subscales to the overall workload score. No significant effects for the subscale dimensions were found for any of the test conditions. Mean subscale ratings are presented in Appendix Table B-5.

Workload Strategies

Information required to identify strategies the BFV crew members used to manage workload was obtained from analyses of the data derived from the post-mission debriefs, video and audio recordings, and the end-of-test questionnaire. Collectively, these sources of information show clearly that the crews did develop some innovative techniques and procedures both to compensate for the problems and to exploit opportunities created by adding Stingray into the BFV system.

However, the very fact that these strategies were developed and that they evolved over successive missions in the field test caused the data to become less structured and less quantifiable than desired. More specifically, the strategies developed by the BFV crews to deal with Stingray-related task demands also caused the performance of the crew members to progressively deviate from that normally dictated by standard BFV operating procedures. Consequently, the crew performance data that were derived from the video and audio recordings and the information obtained from crew members during post-mission debriefings were not consistent

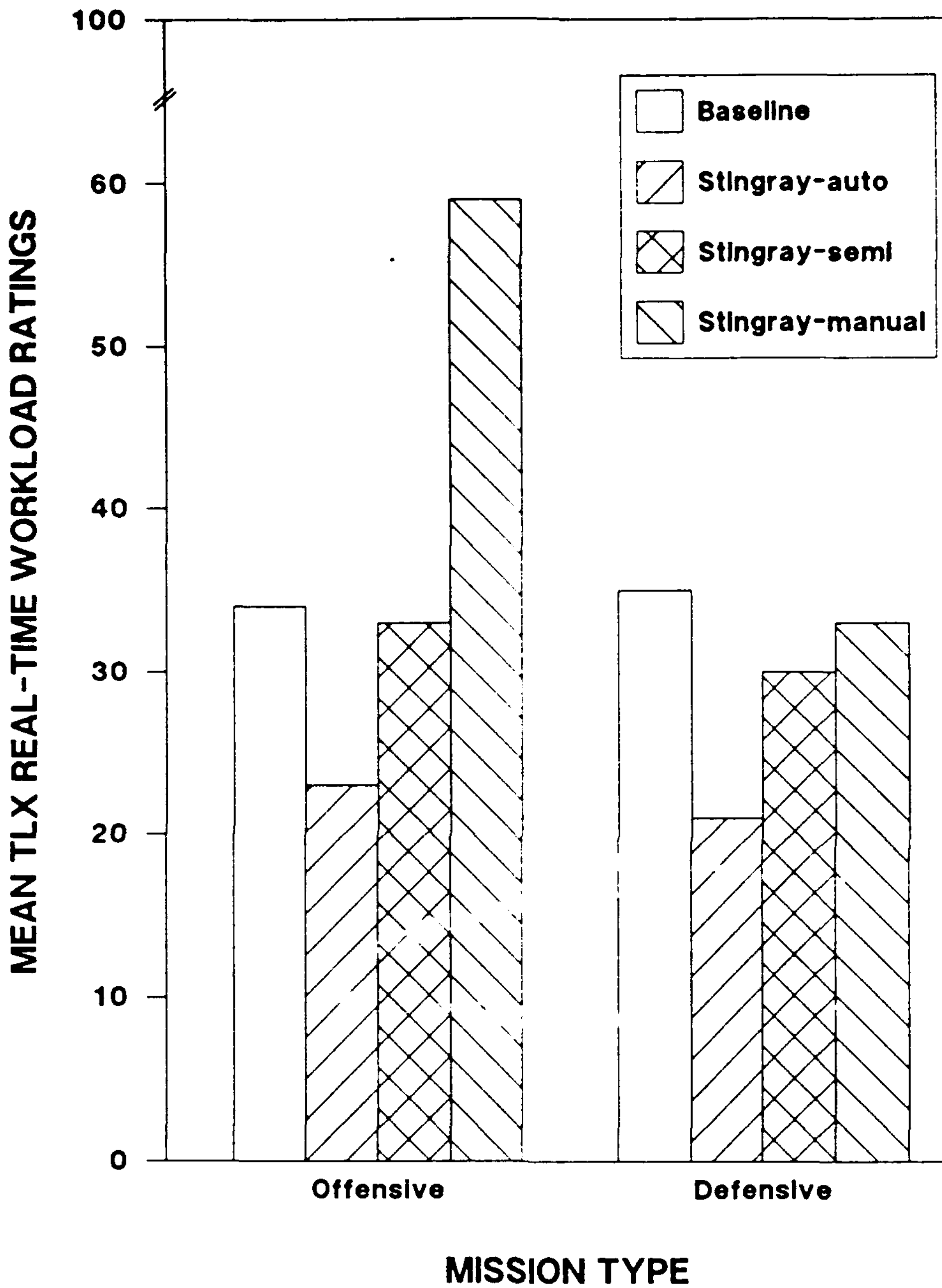

Figure 1. Mean TLX real-time workload ratings by mission type and mode of operation.

over successive missions. Because of the dynamic changes in crew techniques and procedures, the objectives and content of the end-of-test questionnaire also evolved over the field test and was finalized only at the end of the test.

Because of the difficulty encountered in summarizing these data, they are not reported in this section of the report. Instead, because the information derived from these data depends on interpretations provided by the authors, this information is presented in the discussion section which follows. It aids in clarifying the meaning of quantitative workload ratings and performance data.

Workload and System Performance

The relationship between the workload experienced by system operators and the overall performance of the system was examined by calculating the correlation between real-time TLX workload ratings for target acquisition tasks and the force effectiveness ratio (FER). The correlation between workload ratings and system performance is significant for offensive missions (N = 227, r = -.35, p = .0001); the correlation was nearly significant for defensive missions (N = 256, r = - .12, p = .0518). In general, higher levels of BC and gunner workload for target acquisition tasks are associated with lower levels of force effectiveness.

The data obtained for offensive missions best illustrates the nature of the relationship between workload and system performance. These data were summarized and are illustrated in Figure 2. During offensive missions the BCs and gunners experience the greatest workload and FER is lowest for the manual mode of Stingray operations. Least workload and the highest FER are recorded for the automatic mode of Stingray operations. Intermediate levels of workload and FER are recorded for the baseline and Stingray-semiautomatic conditions. During defensive missions the relationship between workload and system performance is much less dramatic. As was reported previously in conjunction with Figure 1, there was little variation in workload ratings during defensive missions. There was a corresponding absence of variation in FER for defensive missions. (Note that FER values are classified and are not presented in this report).

Prospective and Retrospective Workload Ratings

Both TLX and SWORD workload ratings for target acquisition tasks were collected prospectively (at the conclusion of training, but prior to pilot missions) and retrospectively (on the day following the last record mission). Mean prospective, real-time, and retrospective TLX ratings of each crew member for

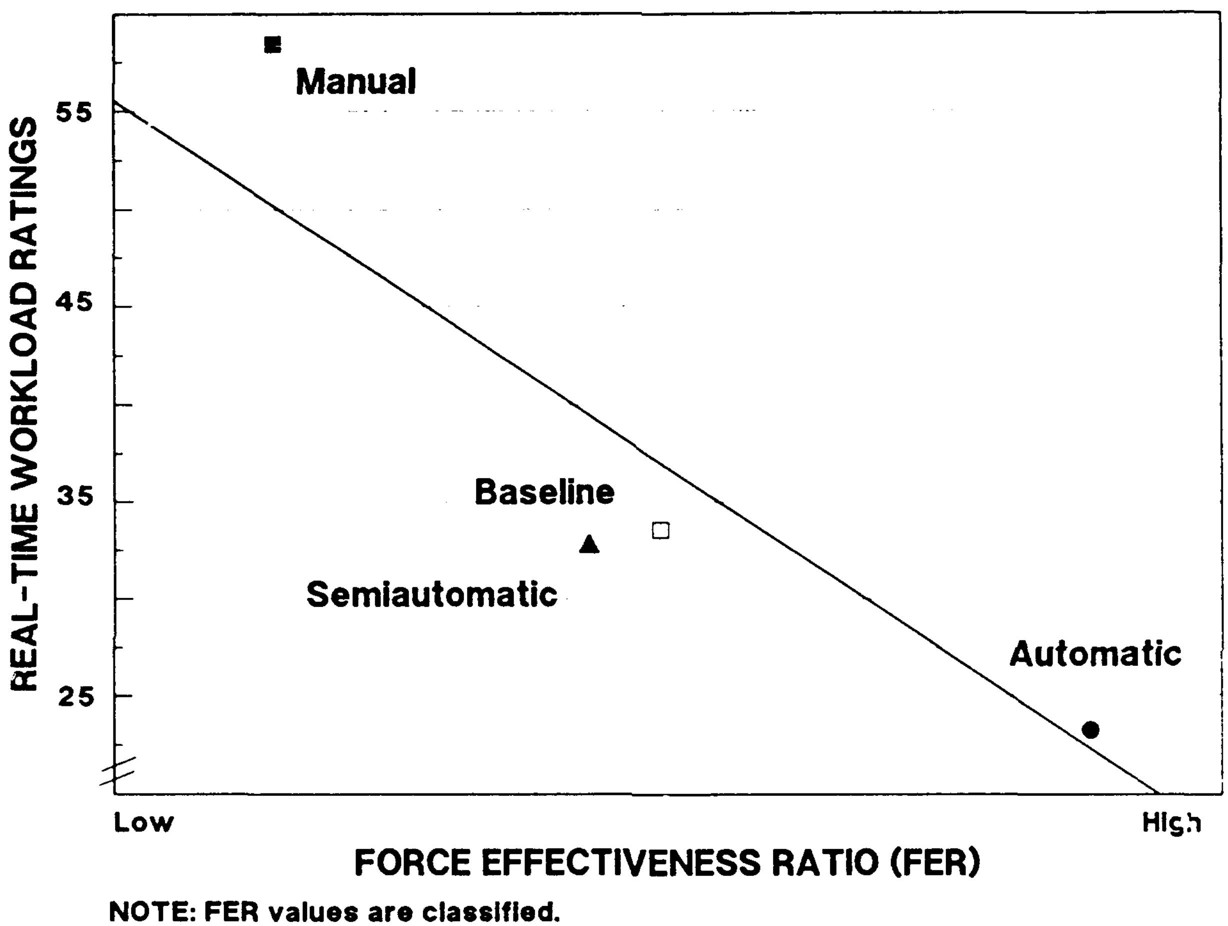

Figure 2. Relationship between workload and force effectiveness for offensive missions.

each combination of mission type and Stingray operations condition are presented in Appendix Table B-6. Mean prospective and retrospective SWORD ratings by task are presented in Appendix Table B-7. Summary means for prospective and retrospective TLX and SWORD ratings are presented for comparison with real-time TLX ratings in Appendix Tables B-8 and B-9, respectively.

Comparisons between workload ratings obtained real-time and those obtained prospectively and retrospectively. The validity of prospective and retrospective workload assessment techniques was evaluated by correlating the ratings each generated with the workload experienced during the missions, as reflected in the real-time TLX ratings. The correlation coefficients were calculated using the mean ratings over crew members for each of the eight combinations of mission type (offensive and defensive) and Stingray operations condition (Baseline, Stingray-automatic, Stingray-semiautomatic, and Stingray-manual) and hence are based on a sample size of $N = 8$.

Prospective and retrospective TLX ratings were compared directly to the real-time TLX ratings. The correlation between prospective and real-time TLX ratings was not significant ($r = .18$, $p > .69$). However, there is a significant correlation between retrospective TLX ratings and real-time TLX ratings ($r = .87$, $p < .01$).

Since the SWORD technique yields relative measures of the workload experienced for each major test condition and TLX yields absolute measures, real-time TLX ratings were normalized for comparison to the SWORD ratings. The correlation between prospective SWORD workload ratings and real-time TLX workload ratings was not significant ($r = .61$, $p > .11$). However, retrospective SWORD ratings were significantly correlated with real-time TLX ratings ($r = .83$, $p < .01$).

Other retrospective workload ratings using the SWORD technique. SWORD ratings were also obtained retrospectively for BFV tasks other than the target acquisition tasks. These tasks were preventive maintenance, checks and services (PMCS), communications, and land navigation. The retrospective SWORD workload ratings for each of these three tasks were subjected to a separate analysis of variance. Factors in each analysis included crew member position (BC or gunner) and mode of operation (Stingray-automatic, Stingray-semiautomatic, Stingray-manual, or Baseline).

Significant differences among the modes of operation were found for only the communications and land navigation tasks. For the communications task, Stingray-manual mode was retrospectively rated relatively higher in workload than the Stingray-automatic and baseline modes of operation but none of these three conditions had a relative workload rating which differed from the

Stingray-semiautomatic mode of operation. For land navigation, all three Stingray modes of operation were rated relatively higher in workload than the baseline condition but they did not differ from each other. A summary of these findings is given in Appendix Table B-10.

Evaluation of Workload Assessment Techniques

The techniques employed during the Stingray CEP included operator workload ratings, post-mission debriefs, video and audio recordings, and an end-of-test questionnaire. The post-mission debriefs proved to be a valuable source of information for understanding the impact of the Stingray system from the perspective of the BFV crew members. The debriefings conducted early in the CEP, to include those conducted following each pilot mission, provided valuable information about some misconceptions by the crews about Stingray operations and how the system was to be utilized. Time was spent with the crews to clarify Stingray operations and the type of information that was being sought for the workload analysis. The qualitative information gained from the debriefs was used in the workload discussion section and in the training section of the Stingray CEP final test report (Williford & Wade, 1990).

However, as was previously reported in presenting the results for workload management strategies, the data derived from the video and audio recordings and the post-mission debriefings were not sufficiently consistent over successive missions to yield reliable results. These data are therefore not reported in this results section. Instead, a discussion of the usability and usefulness of these various techniques for assessing and interpreting workload is presented in the next section. The verbatim responses of all test participants to the end-of-test questionnaire are presented in Appendix C.

DISCUSSION

One objective of this research was to provide information of immediate practical value to the developers and proponents of the Stingray system. Proof that this objective was met is attested to by the fact that the procedures, findings, and recommendations generated by this research effort became integral elements of the Stingray CEP plans, execution, and test report.[1]

[1] In recognition of the success of her efforts in behalf of the Stingray CEP, the senior author received a special commendation and reward from the President of the Air Defense Artillery Board of the U.S. Army TEXCOM.

Meeting this first objective of the present research effort not only speaks well of the abilities and motivation of the research team, it also strongly endorses the totality of the methods employed, from the beginning of the test planning period, through the training and pilot missions, to the completion of the effort. These methods ensured that the workload analyst and data collectors became fully functioning members of the Stingray CEP. Such a totality of involvement with the larger test community must be considered essential whenever there is a desire to meet the needs of the "customer." More on this point will be discussed later in this section.

The second major objective of this research was to generally expand and enhance the Army's capability to assess and evaluate the impact of operator workload. The achievement of this second objective was guided by five research questions, derived from descriptions of an equal number of unresolved workload issues initially given in the introductory section. Succeeding subsections discuss the results of this research as they address each of the five research questions.

What Is the Impact of Stingray Operations on the Workload Experienced by the Bradley Commander and Crew?

Operator ratings indicated that the workload experienced by the Bradley commander and gunner was altered by the addition of the Stingray system to the BFV. A more thorough understanding of these workload ratings was obtained by integrating them with the information obtained from the post-mission debriefs, video and audio recordings, and the end-of-test questionnaire. These latter sources of information also permitted an examination of the workload associated with tasks performed by the driver of the Stingray-equipped BFV.

Bradley commander workload for target acquisition tasks

The results show that the workload reported by the BC for target acquisition tasks was dependent on the Stingray mode of operation and the mission type. The three different modes of Stingray operation require different types and amounts of BC actions. The two types of missions reflect the effects of operating Stingray when the host BFV was on the move (during offensive missions) or stationary (during defensive missions). A more thorough discussion of the workload impact on the BC of each Stingray mode of operation during performance of the target acquisition tasks is presented in succeeding paragraphs.

Stingray-manual mode. The manual mode of Stingray operations require the BC to perform many tasks that are not normally associated with commanding a BFV. These tasks include controlling the search pattern of the STINGRAY with the joystick, detecting and evaluating targets shown in the Stingray visual display, and countermeasuring threats with a trigger pull. As shown in Figure 1 and Table B-4, the manual mode of Stingray operation tended to be associated with greater workload than the other modes of Stingray operation and the baseline condition, particularly while the host vehicle was moving during offensive missions. Even while seated, if the BFV was moving over rough terrain, it was difficult for the BC to manually search the VDU for targets or to use the joystick to place the cross hairs on a target for countermeasure. However, the BCs were rarely seated and tended to perform most of their assigned tasks while standing up in the turret, with much of the upper body protruding out of the hatch.

This upright stance was assumed by the BCs to improve their capability to perform command and control (C2) tasks such as those associated with situational assessment and land navigation. The BCs reported that manually operating the Stingray system is extremely difficult when "out of the hatch." Some BCs tried to concurrently perform Stingray and BFV C2 tasks by riding at "name-tag height" (i.e., halfway out of the hatch). This action did not solve the problem.

The out-of-the-hatch operations performed by the BCs were the subject of much discussion and controversy during the CEP test. Some test personnel advocated that the BC operate the BFV and the Stingray system while seated with the hatch securely closed ("buttoned-up"), as would be the case when troops are under enemy fire. However, the Bradley Fighting Vehicle Gunnery Manual (FM 23-1, 1987) states, "During buttoned-up operations, the Bradley commander's and gunner's ability to acquire targets is reduced by at least 50 percent, and their acquisition responsibilities must be altered" (p. 3-2).

While the Stingray VDU presents the BC with a view of the battlefield other than that provided by the integrated sight unit (ISU) or the vision blocks installed in the hatch, it still presents the BC with only a "slice of the pie." The BCs reported that in order to effectively command and control, they need to be out of the hatch to get the "big picture" of the battlefield, even when under enemy fire.

Stingray-semiautomatic mode. The results show that the semiautomatic mode of Stingray operations imposed the same level of workload on the BCs as the baseline condition (see Table B-4). While in the semiautomatic mode, Stingray automatically searches for, detects, and locates targets, but the BC still must manually perform the tasks of target identification, classification, and countermeasure. Furthermore, the BC must respond to a Stingray target detection signal (via an auditory alarm) within a ten second window. Typically, upon receiving the detection signal, the BC drops down into his seat from out of the open hatch. If the detected target displayed on the VDU is judged to be a threat, the BC manipulates the joystick to place the cross hairs on the target and depresses the countermeasure trigger.

Apparently, the reduction in workload caused by automating the search, detect, and locate tasks is sufficient to offset any gain in workload caused by the requirement to identify, classify, and countermeasure a target judged to be a threat. The BCs did report that the demands of the semiautomated Stingray tasks were made more difficult during offensive missions than defensive missions because the auditory target detection alarm was difficult to hear over the noises made by the BFV while it was on the move. However, the BC ratings did not show any difference in workload due to mission type for the Stingray semiautomatic mode.

Stingray-automatic mode. The BCs rated the workload associated with Stingray in the automatic mode of operation as less than that associated with the other two Stingray modes and the baseline condition. This reduction in workload rating for the automated mode of operations occurred for both offensive and defensive missions. The reduced workload was particularly pronounced for the target acquisition tasks of searching, detecting, and locating targets (see Table B-3).

The real-time ratings of workload experienced with the automatic mode of Stingray operations were higher than what the BCs predicted using the prospective rating technique (see Table B-8). The BCs indicated at the end of training (but prior to the pilot missions) that they thought Stingray would automatically take care of the threat. However, on the end-of-test questionnaire, the BCs commented that Stingray is to be considered "an extra pair of eyes," not a replacement for the target acquisition responsibilities of the BC. One BC commented, "Automatic mode is not any more independent of the BC than cruise control is for a driver" of an automobile.

Bradley commander and gunner workload for target acquisition tasks

The rating data showed that the Bradley gunner and BC experienced similar shifts in workload over combinations of Stingray modes of operation and mission types. In fact, the gunner tended to experience more workload than the BC over these test conditions (see Table B-4). Information derived from sources such as the end-of-test questionnaire suggest that the workload experienced by both the BC and gunner during performance of the target acquisition tasks are due to changes these crew members made in operating procedures. Three of these changes in target acquisition procedures are discussed in succeeding paragraphs.

1. Since the Stingray system automatically provides the gunner with target range and azimuth information, there is little or no need for the BC to verbally give this target position information to the gunner as prescribed in BFV target handoff procedures. As a result of this "automation" of target handoff information, the workload of both the sender (BC) and receiver (gunner) of that information is similarly affected for all modes of operations.

2. During semiautomatic and manual operation of the Stingray system the BC must give priority to the performance of a number of Stingray-specific actions. Consequently, a number of tasks normally performed by the BC were, instead, performed by the gunner. One critical task whose performance was shown to be transferred from the BC to the gunner is that of traversing the turret to orient the BFV conventional weapon systems toward the location of a target to be engaged.

3. With Stingray added to the BFV, the role of the BC and gunner may change during the performance of tasks associated with searching for targets, target detection, and target prioritization. Changes in the demands these tasks placed on the BC and gunner are discussed in the next three paragraphs.

(a) Gunners reported that they searched for targets outside their assigned sector in order to acquire information provided by Stingray for the rest of the platoon and Blue force. Normally, the gunner will use the ISU to scan only his assigned sector and, concurrently, orient the BFV weapon systems in the general direction of suspected or known threats for targets. When in the automatic and semiautomatic mode, Stingray searches sectors aligned with the horizontal line of sight of the 25-mm gun. Therefore, by expanding his sector of search, the gunner also increased the size of the sector searched by Stingray. One gunner, for example, reported that he was scanning out of his assigned sector so that Stingray "had a full view".

(b) Gunners assisted the BC in detecting targets for Stingray countermeasure. When a gunner detected targets out of the Stingray's field of regard, he would relay this information to the BC. Given this information, the BC could use a sector switch to change the Stingray search pattern. With increasing amounts of experience with the Stingray system, the BFV crews discovered that the quickest way to bring Stingray onto the target detected by the gunner was to have the BC depress the Stingray "stop/scan" switch which immediately cages the Stingray on the 25-mm gun line of sight. This was an innovation in

Stingray employment identified and implemented by the crews in the test platoon -- not a procedure included in Stingray training.

(c) With Stingray, the gunner (rather than the BC) may need to establish target priority, particularly in a multiple target scenario. The Stingray system prioritizes targets on the basis of only their range, not by type of threat. Normally, the key factor in determining the priority for engagement is the target's eminent threat to friendly force survival. For example, a threat tank, with its greater killing capability, has a higher engagement priority thar a threat mechanized infantry vehicle, say, a BMP. This is t. .e even if the BMP is at a shorter range. Consequently, the gunner may not rely solely on the order of target presentation in the Stingray range and azimuth display. Stingray's capabilities also may alter target prioritization in other ways. For example, in one mission the gunner reported that there were two targets in view. The gun of one target was facing towards the Stingray BFV and that of the other target was oriented away from the Stingray vehicle. The gunner opted to engage the one "not looking," figuring that Stingray would take care of the one "looking."

Bradley commander and gunner workload for other tasks

Stingray also affected the workload ratings of the BC and gunner for BFV tasks other than those associated with target acquisition. These workload data were obtained from the retrospective administration of the SWORD technique (see Table B-10). The workload associated with the tasks of preventive maintenance, checks, and services (PMCS), communications, and land navigation is discussed in succeeding paragraphs.

PMCS. The addition of the Stingray system to the BFV requires some increase in the numbers and types of PMCS tasks. However, the crews never had to perform any of these new PMCS tasks during the CEP. All PMCS and other maintenance and repair of the Stingray system were performed by contractor personnel. Thus, the retrospective workload ratings assigned to the PMCS task did not vary as a function of mode of operation. The slightly higher ratings for the three Stingray modes of operation over the baseline condition were due to the crews' understanding of additional system requirements, and not on actual experience.

Communications. The workload associated with BFV communication tasks tend to be rated higher when the baseline BFV was augmented with Stingray. This increase in workload was statistically significant for the Stingray-manual mode of operation. This effect may be attributed partly to a persistent problem encountered with the headset mounted in the Combat Vehicle Crewmember (CVC) helmet. Because the CVC headset did not operate correctly, the BC was required to hand-hold a receiver between the inside of the helmet and his ear. Consequently, when Stingray was operated in the manual mode, the BC had to use one hand to hold the receiver to his ear and the other to operate the Stingray joystick. These requirements left no hand free for the BC to stabilize himself while he was out of the hatch or while the BFV was moving over rough terrain during offensive missions.

The workload associated with BFV communication tasks was also rated higher under Stingray conditions because the BCs engaged in more communications. The BCs reported that they felt an increased emphasis to provide spot reports due to Stingray's capability to detect targets earlier and at greater range. The accurate target range information provided by Stingray allowed the Blue force to withhold engagement until the BFV weapons were within their respective firing ranges.

Land navigation. Retrospective workload ratings for the land navigation tasks performed by the BC increased when the Stingray system was operated, especially if it were operated in the semiautomatic or manual mode. Since the BC is required to perform Stingray-related tasks inside the BFV turret, there was a decrease in the amount of time the BC could spend out of the hatch, assessing the terrain and giving directional assistance to the driver.

Driver Workload

The workload imposed on the crew of a Stingray-enhanced BFV extends to the BFV driver. An experienced driver may be critical for effective operation of Stingray by the BC. The additional workload imposed upon the driver of a Stingray-enhanced BFV is discussed in the following four paragraphs.

Land navigation. The Stingray system increased the demand on the driver to demonstrate land navigation skills. It has been established that the BC must be either inside or looking inside the BFV turret to properly operate Stingray in its semi-automatic and manual modes of operation. This fact prevents the BC from being "out of the hatch" to acquire detailed land navigation information to pass on to the driver. An experienced driver, able to make more independent land navigational decisions, is therefore required to reduce the amount of time the BC needs to spend out of the hatch for navigational purposes.

Smooth ride. The Stingray system increased the demand on the driver to move the BFV over the smoothest possible terrain. It has been established that during cross-country movement, the BC is physically thrown around within the turret, especially when standing up out of the hatch. This physical jarring and jolting increased when the BC is attempting to operate the Stingray system. For example, the BC must dedicate one hand to manipulating the joystick in the semiautomatic or manual modes of Stingray operation. This requirement leaves one less hand free to stabilize the body. The crews also reported that there were more Stingray system failures when the BFV bounced hard over the rough terrain, such as over sand dunes. These examples clearly demonstrate a need for the driver to select and move the BFV over the smoothest route possible.

Vehicle positioning. The Stingray system increased the demand on the driver to select and assume level stationary battle positions. Proper positioning of the BFV is important if the Stingray system is to operate effectively. The Stingray system used in the CEP test was aligned with the "water line" of the test BFV (i.e., with the hull of vehicle). If the Stingray BFV was positioned "hull up" then the Stingray search beam would be pointed upward toward the sky. To make matters worse, the Stingray's vertical orientation is not readily apparent to the BC in automatic and semiautomatic modes. No picture of the search pattern is presented on the Stingray VDU in the automatic mode and a target detection is necessary before a picture is presented in the semiautomatic mode. Consequently, the driver must be able to quickly park the Stingray BFV in a level position.

Stingray power requirements. The Stingray system tested in the CEP was powered from the BFV engine. The drivers explained that it was necessary to "rev up" the host BFV engine in order to provide enough power for Stingray system operations. This resulted in a demand on the driver to monitor and properly maintain adequate sources of BFV electrical power. They also noted that the increased noise and exhaust fumes caused by revving up the BFV engine could allow the enemy to identify the Stingray-equipped BFV and its position.

Workload of the BFV crew

The crew of the BFV augmented with Stingray may be required to provide more "soft and hard kills" than other BFV crews in the platoon. Since Stingray can be used to delay enemy fire, the BC may try to countermeasure (soft kill) all possible threats so the platoon can continue its advance during offensive operations. Since Stingray can rapidly detect and provide range and azimuth information for potential targets, the gunner in the host BFV may have the earliest, most accurate target data necessary to destroy (hard kill) threat systems using conventional weapons. These advantages of employing Stingray and the corresponding increase in workload is more pronounced in a multiple target field.

One gunner commented, "The range information helps the gunner to engage targets with better first round hit probabilities." Also, the Stingray platoon leader said he felt "bolder" when on the attack with Stingray in his platoon. He advanced his platoon closer to the objective knowing that Stingray could delay fire from the threat while the platoon laid down a base of fire in the overwatch position. Thus, there may be more reliance on the Stingray crew to scan with Stingray out of their assigned sector, detect a greater number of targets, and engage targets sooner than other BFV crews in the force.

What Workload Management Strategies Are Employed by the Crew of the Stingray-Augmented BFV?

In general, when faced with high task demands, operators may adopt any number of strategies in an attempt to achieve and maintain acceptable levels of workload and performance. For crew operations, as is the case with the BFV, tasks may be reallocated among crew members in an effort to redistribute the workload. As discussed in the previous section, the requirement to operate the Stingray system was accompanied by changes in a number of BFV standard operating procedures.

The workload strategies employed by the Stingray crew were identified through information obtained from crew debriefs, the end-of-test questionnaire, and the audio and video recordings. An analysis of this information clearly shows that the closely interwoven functions of the BC, gunner, and driver of the test BFV were modified with the addition of the Stingray system.

It was found that the BC shed tasks to the gunner or, alternatively, the gunner assumes the responsibility to perform tasks that are normally assigned to the BC. For example, the BC is trained to follow a standard target handoff procedure in which he directs the gunner to a target by verbal command (i.e., the BC gives range information and identifies target type) and traverses the turret to face the threat. However, with Stingray, the BC countermeasured targets with the system which, in turn, relayed target position information directly into the gunner's display. Therefore, the gunner can and does traverse the turret and engage targets without any formal handoff procedures. Details of these task modifications are presented in a previous section on Bradley commander and gunner workload.

The driver of the Stingray vehicle also assumed a portion of the functions and tasks normally assigned to the BC. For example, it was difficult for the BC to both operate Stingray in the manual or semiautomatic modes and give navigation information to the driver. For missions using either of these two Stingray modes, the BCs gave the driver less specific directional information. As a result, the driver assumed more responsibility for selecting routes and stationary positions that gave Stingray the best possible windows of opportunity.

What Is the Relationship Between Workload and System Performance?

A relationship between real-time workload ratings and system performance was found -- higher levels of crew workload were associated with lower levels of force effectiveness. Crews experienced the greatest workload in the Stingray manual mode that, in turn, was associated with the lowest force effectiveness ratio (FER). Least workload and the highest FER were recorded for the automatic mode of Stingray. High FER values indicate that proportionally fewer friendly vehicles were destroyed than enemy vehicles.

Clear relationships between workload and performance are not always found. It is suggested that such a relationship was demonstrated in this test for several reasons. First, the operator actions required by the three operating modes of Stingray were differentially demanding enough to be reflected in the workload ratings. Second, the tasks selected for workload ratings were relevant to the objectives and mission of the Stingray system. Third, the measure of system performance used (i.e., the FER) was appropriate since Stingray is designed to protect friendly forces from fires.

Therefore, the present study clearly demonstrates that a relationship between workload and system performance is most likely to be found for those cases in which the following conditions are true:

1. Workload ratings reflect differential system demands,
2. Tasks selected for workload ratings impact system performance, and
3. System performance measures are related to designated system objectives.

What Is the Relationship Between Both Prospective and Retrospective Workload Ratings and Real-Time Workload Ratings?

One of the objectives of the present research was to evaluate the utility of using workload rating scales as prospective (i.e., predictive) and retrospective measures of the "real-time" experience of workload. Improved analytical techniques are required to predict workload early in system development where the greatest design flexibility is available with the least impact on system cost. Retrospective measures of workload are important in situations in which the opportunity to collect "real-time" workload data is hindered, such as in an operationally significant field environment. The Stingray CEP provided a unique opportunity to gather workload ratings prospectively, real-time, and retrospectively from one set of subjects.

Analyses revealed no significant correlation between prospective ratings using either the TLX or SWORD instruments and real-time ratings using TLX. The failure of the BCs and gunners to successfully use either absolute or relative measurement scales to predict real-time ratings of workload may have been due to the Stingray training they received. That training clearly was not sufficient to provide crew members with the expert knowledge necessary to correctly predict variations in the workload they would experience operating a BFV whose capability was augmented with a Stingray system.

Hence, while these soldiers might well be considered subject matter experts on all or most aspects of BFV operations, they were not experts on the operational characteristics of the Stingray system nor, most importantly, on the interaction of Stingray and BFV operating characteristics. Indeed, there is some evidence that the Stingray-specific and Stingray-in-a-BFV knowledge of the crews was still increasing at the conclusion of the CEP field test. The question of the types and amounts of knowledge needed to qualify someone as a subject matter expert was not raised as a research question for this study. However, it is a question which must be answered if we are to ask an individual to make reasonable predictions of the workload (or any other attribute) associated with the operation of a system.

Significant positive relationships were found for the retrospective workload ratings using either the TLX or SWORD techniques and the real-time ratings using TLX. The results clearly show that either of these two rating techniques can be used by BFV crew members to quantify the workload they experienced during an earlier period of time. There is no evidence to suggest that the memory of those earlier experiences decayed or was inhibited over the six weeks of testing.

How Useful Are the Various Techniques Employed During the Stingray CEP for Assessing and Interpreting Workload and Performance?

TLX. There is no evidence that BFV crew members had any difficulty using the NASA-TLX workload measurement technique to report their real-time perception of workload. The results obtained using the TLX scale show face validity in that the test conditions which were clearly different in the demands they imposed on the operators were associated with correspondingly different TLX workload ratings. The validity of TLX was also demonstrated by the relationship between the TLX ratings and a measure of system performance, the force effectiveness ratio.

The prospective and retrospective uses of the TLX technique were discussed in the previous section of this report. It is sufficient to note here that prospective and retrospective applications of TLX have been previously reported (see Hill, Zaklad, Bittner, Byers,& Christ, 1988, and Hill, Byers, Zaklad,& Christ, 1988, respectively). However, the present study is the first to assess the validity of TLX as a retrospective and prospective technique through correlations with real-time operator ratings.

SWORD. SWORD is a recently developed instrument and has been used primarily in studies with Air Force pilots. The Army BFV crews had some difficulty understanding the SWORD workload instrument as it was initially administered in this study (i.e., at the conclusion of Stingray training). When analysts questioned some crew members about inconsistencies in their ratings, it was discovered that some had marked ratings the opposite of what they had intended. After making some modifications in the prospective workload instrument (i.e., changing scale labels from those used previously, see Appendix A-2), the crews were able to use SWORD retrospectively at the conclusion of the test with less apparent difficulty.

However, even after modifying the SWORD instrument, it is concluded that SWORD was more difficult to administer and the workload ratings it produced were more difficult to score and analyze than TLX. Furthermore, there is no evidence that the relative measures of workload produced by SWORD have any advantage to or are quantitatively different from normalized TLX scores. In the present study, the prospective and retrospective use of SWORD and TLX yielded essentially identical results.

Debriefs. The after-mission interviews or debriefings that were conducted with the BFV crews yielded much information of general value to this effort. For example, after pilot test missions, the crews were debriefed and were administered workload rating scales just as they would be during the record missions. This provided an opportunity for the crews and the test team to clarify any misconceptions that existed about Stingray operation, force tactics, test conduct, and data collection. Many valuable bits of information were gained during this "test drive" of Stingray which led to initial insights about workload issues and refinement of debriefing questions by the workload analyst.

Once into the test, the post-mission debriefs with the crews provided vital information used to clarify the workload ratings and to identify the workload strategies employed by the crew. In addition, important information was obtained regarding other concerns of the CEP, such as those related to training, tactics, safety, and human engineering design.

Video and audio recordings. Measures of crew performance were to be obtained from the video and audio recordings. According to prescribed BFV procedures, there is a progressive interactive verbal exchange of information between the BC and gunner, beginning with a target alerting command by the BC and continuing to the gunner's announcement of weapon fire, "on the way." Based on these written procedures, it was anticipated that performance time and error measures could be extracted from the video and audio recordings of crew actions during a mission. These measures were then to be related to the ratings of workload and measures of system performance.

However, with Stingray, the BC and gunner either eliminated or only partially followed the standard BFV operating procedures. This may have been due in part to the capability of Stingray to detect and locate targets. It may also be due to insufficient crew training on how to integrate Stingray operations into routine BFV task procedures. As a consequence of the crews' deviation from accepted BFV operating procedures, there were no consistent indicators on the recordings from which to derive crew performance measures. However, the video and audio tapes did provide an objective record of crew actions which served to clarify the self-report of actions by the crews.

End-of-test questionnaire. The structured end-of-test questionnaire provided information which was quite valuable for interpreting information available from other sources. The objectives and, correspondingly, the contents of the end-of-test questionnaire evolved over the course of the CEP and were finalized towards the end of the test.

It was of particular importance that the end-of-test questionnaire obtain information from the crews about the effects of Stingray on task performance. This importance was underscored as a result of the crew-initiated departure from BFV standard operating procedures and the absence of reliable crew performance data in the video and audio recordings. The questionnaire also contained items that elicited much useful information from the crews concerning topics such as future training needs (e.g., safety, tactics, tips on Stingray operation) and desired modifications to the system (e.g., hardware and software fixes).

CONCLUSION

The findings obtained in this research provided information of immediate practical value to the developers and proponents of the Stingray system. The workload assessment findings are helpful not only in pinpointing areas of potential difficulty (e.g., high workload for Stingray-manual in offensive missions) but also areas of benefit (e.g., reduced workload for Stingray-automatic). This information can be used to guide many "soldier-in-the-system" decisions. For example, early in system development some problems may be alleviated through human engineering design (e.g., yoke Stingray components to the gunner's station so the gunner can operate the system when the BC has other task demands). Evidence of workload management strategies, such as the reallocation of tasks between the BC and gunner, may be used to guide new training doctrine for the employment of Stingray. Workload findings may drive changes in tactics, such as guidance to generally employ the automatic mode of Stingray operations, especially during attack missions, and to use the manual mode of operations only for situations which present a clear danger of fratricide.

Soldier-oriented issues, such as operator workload, do not always receive the attention they should. However, they are more likely to "speak" to the decision makers when they are tied in with system performance. In the Stingray CEP, it was clearly demonstrated that the types and amounts of operator actions required by each of the operating modes of Stingray are associated with different levels of workload as well as changes in force effectiveness. It is important to stress that workload problems noted in field testing, where there are less serious consequences of failure, may be exacerbated in battlefield operations. During the stress of battle, the same workload problems may significantly reduce the likelihood of a successful mission. It is these types of findings which demand attention from the decision makers.

This study also provides findings of immediate practical value to those charged with the responsibility for assessing workload and interpreting its impact on soldier and system performance. From a methodological perspective, this study demonstrated two critical and interrelated preconditions for successful field studies of workload.

First, it was shown that a thorough workload assessment relies on early preparation and total participation. The workload analyst must become "system smart" and develop close working relationships with all the other test personnel and players. The workload analyst must also begin gathering workload information as soon as possible in order to gain initial insights and refine data collection techniques. Since a field test undergoes many changes throughout its planning and execution phases, the analyst must be flexible in how to best obtain the data relevant to the research objectives. For example, if crew performance (i.e., task performance time and error) were the only workload measure planned in the present study, the assessment of workload in this study would have been severely compromised. It was not apparent until several test missions had occurred that these data would be unobtainable.

Second, since workload is a function of many variables, it is necessary that multiple, redundant techniques and sources of information be employed to assess workload. This is particularly important in a field test situation which is characterized by many uncontrolled variables and uncontrollable conditions. In this type of environment, the total workload picture can only be gained through the integration of a "patchwork" of bits of information, such as were utilized in this study (i.e., operator workload ratings, post-mission debriefs, video and audio recordings, and a post-test questionnaire).

Another conclusion from this research supports the position that a well developed workload assessment program will permit an examination of the workload imposed upon a crew or team of individuals while they jointly operate a system. The capability to analyze crew workload permits an examination of the effects of crew member coordination and shared task performance on the management of workload and the optimization of system performance.

Finally, this research supports the position that operators can use rating techniques retrospectively to report the workload they experienced during an earlier period of time. This conclusion is important since it is often not possible to obtain workload ratings during or immediately following a period of performance. The research was not able to demonstrate that operators can use rating techniques prospectively to predict the workload they would experience in some future system or future operating environment. This latter result raises the issue of the types and amounts of knowledge and experience necessary to qualify someone as a subject matter expert.

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APPENDIX A

WORKLOAD INSTRUMENTS

CONTENTS

NASA Task Load Index (TLX)

TLX is a workload assessment technique which elicits absolute judgments of workload on a scale from 0 to 100 (low to high workload). It is comprised of six workload dimensions; 1) mental demand, 2) physical demand, 3) temporal demand, 4) performance, 5) effort, and 6) frustration.

TLX accounts for differences among individuals in their perception of workload for specific tasks. The individual weighting procedure requires the rater to designate the more relevant dimension of workload from all possible pairs of the six dimensions (a total of 15 pairwise comparisons). In the present study, crew members were presented with 15 separate slips of paper. Each slip of paper listed two of the dimensions (e.g., temporal demand and mental demand). The crew members circled which of the two dimensions contributed more to the experience of workload when performing target acquisition tasks. The proportion of times each workload dimension was judged to be more relevant than the other dimensions was used to weight the ratings. A unique weighting scale was thus developed for each crew member.

Six tasks in the target acquisition process were rated using the TLX scale. These tasks were; 1) search for targets, 2) detection (discovery of targets), 3) location (determine target position), 4) identification (recognize target type), 5) classification (prioritize targets), and 6) target handoff (coordination between the BC and gunner for target engagement). Each of these tasks was rated for workload demand for each combination of mission conditions (offensive or defensive) and mode of operation (baseline or one of the three modes of Stingray operation).

When used prospectively, half of the crewmembers rated offensive and half rated defensive missions. This was done to reduce the number of ratings elicited, since prospective ratings included daytime and night missions. Since night missions were cancelled during the test, retrospective ratings were obtained from all the crews for both offensive and defensive missions.

The prospective and retrospective TLX ratings for the target acquisition tasks were examined for possible correlation with the real-time TLX ratings. The real-time TLX ratings were analyzed to determine any mission condition effects on workload and examined for any differential contribution of the six subscale dimensions (e.g., effort, frustration) to the experience of workload.

For illustration, one of the pages from the TLX real-time workload rating forms follows.

MODE OF OPERATION: Stingray-manual

MISSION TYPE: Offensive

Task or Mission Segment: IDENTIFICATION (recognize target type)

Please rate the task or mission segment by putting mark on each of the six scales at the point which matches your experience.

Mental Demand

0 100

(HOW MENTALLY DEMANDING WAS THE TASK?)

Physical Demand

0 100

(HOW PHYSICALLY DEMANDING WAS THE TASK?)

Temporal Demand

0 100

(HOW HURRIED OR RUSHED WAS THE PACE OF THE TASK?)

Performance

Perfect Failure

(HOW SUCCCESSFUL WERE YOU IN ACCOMPLISHING THE TASK?)

Effort

0 100

(HOW HARD DID YOU HAVE TO WORK TO ACCOMPLISH YOUR LEVEL OF PERFORMANCE?)

Frustration

0 100

(HOW INSECURE, DISCOURAGED, IRRITATED, AND ANNOYED WERE YOU?)

Subjective Workload Dominance (SWORD)

SWORD is a relative workload assessment technique. SWORD provides a method to extract expert judgments about workload for tasks in relation to other tasks or for alternative system designs. All possible pairs of items (tasks, mission conditions, etc.) to be compared are presented to the rater. If one of the pair is judged to have higher workload, then the rater judges how much higher on a scale from 1 - 8.

The comparisons are used to fill a judgment matrix in which each row represents one item's workload dominance relative to all of the other items. The next step is to estimate the true ratio scale underlying the rater's judgments. Saaty (1980) proposed a normalized eigenvector scale, however others have suggested a geometric means approach (Vidulich, 1989; Williams & Crawford, 1980*). The geometric means approach may be more compatible with existing statistical techniques, easier to understand and to calculate. This approach was used in the present study. The data can then be subjected to statistical analyses.

After observing some difficulty by the crews in understanding the scale when used prospectively (i.e., at the conclusion of Stingray training), the SWORD instrument was modified for the retrospective administration. Verbal anchors for the scale were changed from "absolute, very strong, strong, weak, and equal" to the more appropriate labels of "extremely high relative workload, very much higher, moderately higher, slightly higher, and equal workload".

Crew members assessed the direction and magnitude of the difference in workload for each task under all possible pairs of mission conditions. The mission conditions consisted of the three modes of Stingray operation and the baseline condition for offensive and defensive missions. Tasks included the six target acquisition tasks (search, detect, locate, identify, classify, and target handoff) and other BFV tasks of PMCS (preventive maintenance, checks and services), communications, and land navigation.

The prospective and retrospective SWORD ratings for the target acquisition tasks were examined for possible correlation with the real-time TLX ratings. The retrospective SWORD ratings for the other BFV tasks were analyzed to determine any mission condition effects on workload.

The example sheet and one of the pages from the SWORD retrospective rating packet is included for illustration.

*Williams, C., & Crawford, G. (1980, May). Analysis of subjective judgment matrices (Technical Report R-2572-AF). Santa Monica, CA: Rand.

EXAMPLE SHEET

	EXTREMELY HIGH RELATIVE WORKLOAD	VERY MUCH HIGHER	MODERATELY HIGHER	SLIGHTLY HIGHER	EQUAL WORKLOAD	SLIGHTLY HIGHER	MODERATELY HIGHER	VERY MUCH HIGHER	EXTREMELY HIGH RELATIVE WORKLOAD	
EXAMPLE 1 - Tasks X and Y are EQUAL in Workload										
X					✔					Y
EXAMPLE 2 - Task Y causes a little more Workoad.										
X						✔				Y
EXAMPLE 3 - Task Y causes a lot more Workload.										
X									✔	Y
EXAMPLE 4 - Task X causes somewhat more Workload.										
X			✔							Y

TASK: Detection (discovery of target) CONDITION: DAY

	EXTREMELY HIGH RELATIVE WORKLOAD	VERY MUCH HIGHER	MODERATELY HIGHER	SLIGHTLY HIGHER	EQUAL WORKLOAD	SLIGHTLY HIGHER	MODERATELY HIGHER	VERY MUCH HIGHER	EXTREMELY HIGH RELATIVE WORKLOAD	
					OFFENSE					
BASELINE										STINGRAY -AU
BASELINE										STINGRAY -SE
BASELINE										STINGRAY -MA
TINGRAY -AUTO										STINGRAY -SEM
TINGRAY -AUTO										STINGRAY -MAN
TINGRAY -SEMI										STINGRAY -MAN
					DEFENSE					
BASELINE										STINGRAY -AUT
BASELINE										STINGRAY -SEM
BASELINE										STINGRAY -MAN
TINGRAY -AUTO										STINGRAY -SEMI
TINGRAY -AUTO										STINGRAY -MAN
TINGRAY -SEMI										STINGRAY -MAN

END-OF-TEST QUESTIONNAIRE

STINGRAY QUESTIONNAIRE NAME ________________

I. TASK PERFORMANCE and WORKLOAD

1. In what ways has STINGRAY changed how you accomplish your tasks? (e.g., have you dropped any less important tasks in order to accomplish STINGRAY tasks, have other crew members picked up some of the tasks you normally do)

2. Do you think the principal operation of STINGRAY should be in the BC's station (as it was tested) or should it be moved to another crew member's (e.g., gunner)? Why or why not?

3. How often did STINGRAY pick up targets that you had not already detected by other means (e.g., ISU, reports from others in Force)?

   a) Auto mode

   never | ____ | ____ | ____ | ____ | ____ | ____ | very often

   b) Semi-auto mode

   never | ____ | ____ | ____ | ____ | ____ | ____ | very often

   c) Manual mode

   never | ____ | ____ | ____ | ____ | ____ | ____ | very often

4. How useful was the range/azimuth information displayed by STINGRAY to you in engaging targets with BFV conventional weapons?

no difference from baseline missions | ____ | ____ | ____ | ____ | ____ | ____ | very useful

5. What percentage of the time is the BC commanding out of the hatch?

   a) on the attack ____% b) on the defense ____%

6. What percentage of the time are you looking through BFV optical sights?

   a) on the attack _____%   b) on the defense _____%

7. Do you think STINGRAY affected your performance during the missions?

   Give a number on a scale of -10 to + 10, where
   -10 = greatly reduced my performance
   0 = made no difference in my performance
   +10 = greatly improved my performance

   a) Overall performance of my duty position

ATTACK		DEFEND	
_____	STINGRAY-AUTO	_____	STINGRAY-AUTO
_____	STINGRAY-SEMI	_____	STINGRAY-SEMI
_____	STINGRAY-MANUAL	_____	STINGRAY-MANUAL

   COMMENTS:

- -

   b) Search for targets

ATTACK		DEFEND	
_____	STINGRAY-AUTO	_____	STINGRAY-AUTO
_____	STINGRAY-SEMI	_____	STINGRAY-SEMI
_____	STINGRAY-MANUAL	_____	STINGRAY-MANUAL

   COMMENTS:

- -

   c) Detection (discovery of targets)

ATTACK		DEFEND	
_____	STINGRAY-AUTO	_____	STINGRAY-AUTO
_____	STINGRAY-SEMI	_____	STINGRAY-SEMI
_____	STINGRAY-MANUAL	_____	STINGRAY-MANUAL

   COMMENTS:

d) Location (determine target position)

ATTACK

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

DEFEND

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

COMMENTS:

- -

e) Classification (prioritize targets)

ATTACK

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

DEFEND

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

COMMENTS:

- -

f) Identification (recognize target type)

ATTACK

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

DEFEND

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

COMMENTS:

- -

g) Target handoff

ATTACK

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

DEFEND

_____ STINGRAY-AUTO

_____ STINGRAY-SEMI

_____ STINGRAY-MANUAL

COMMENTS:

h) Employ BFV weapon systems

ATTACK		DEFEND	
______	STINGRAY-AUTO	______	STINGRAY-AUTO
______	STINGRAY-SEMI	______	STINGRAY-SEMI
______	STINGRAY-MANUAL	______	STINGRAY-MANUAL

COMMENTS:

- -

i) Commo

ATTACK		DEFEND	
______	STINGRAY-AUTO	______	STINGRAY-AUTO
______	STINGRAY-SEMI	______	STINGRAY-SEMI
______	STINGRAY-MANUAL	______	STINGRAY-MANUAL

COMMENTS:

- -

j) Land navigation

ATTACK		DEFEND	
______	STINGRAY-AUTO	______	STINGRAY-AUTO
______	STINGRAY-SEMI	______	STINGRAY-SEMI
______	STINGRAY-MANUAL	______	STINGRAY-MANUAL

COMMENTS:

- -

h) Command and control

ATTACK		DEFEND	
______	STINGRAY-AUTO	______	STINGRAY-AUTO
______	STINGRAY-SEMI	______	STINGRAY-SEMI
______	STINGRAY-MANUAL	______	STINGRAY-MANUAL

COMMENTS:

II. SAFETY

1. Does STINGRAY pose any particular health or safety hazards to user personnel?

2. How concerned were you about your own health and safety whenever you were in close proximity to the STINGRAY vehicle?

   a) during the conduct of this test

not concerned at all ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ very concerned

   b) during an actual battle with STINGRAY at its full capabilities

not concerned at all ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ very concerned

3. Do you feel the safety procedures utilized during this test need any improvement? If so, then please explain.

III. TRAINING

1. How would you rate the training you received on STINGRAY operations?

Poor ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ Excellent

2. How would you rate the STINGRAY operator's manual?

Poor ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ Excellent

3. How useful was the condensed version of STINGRAY operator's manual?

no help at all ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ very useful

4. Do you have any comments or suggestions about how to improve the STINGRAY training for future crews?

5. If you were to pass along any tips about STINGRAY operations and functions, what would they be?

6. Do you feel that personnel need any additional/specific skills or aptititudes to effectively operate STINGRAY (other than what is currently required for your MOS)?

IV. PERFORMANCE

1. In general, the survivability of the Blue Force was due to

BLUE ATTACK	BLUE DEFEND	
________%	______%	presence/absence of STINGRAY
________%	______%	tactics employed
________%	______%	personnel
________%	______%	instrumentation (e.g., MILES)
________%	______%	other _____________

NOTE: these should add up to 100%

2. How would you tactically deploy STINGRAY on the defense and attack?
Please include your recommendations for where to position it in the formation, how many STINGRAYs should a platoon or a company have, what mode (Auto, Semi, Manual) of operation(s) would be best, would it work to have STINGRAY in the Platoon Leader's or Sergeant's or even Company Commander's vehicle?

a) on the defense:

b) on the attack:

c) any other comments about tactics:

3. How useful was the target position information relayed by the STINGRAY crew to the rest of the Blue Force?

no difference from baseline missions ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ ____ ¦ very useful

4. Do you think STINGRAY accomplished its goal of delaying the Red Force's fire so that the Blue Force could engage the enemy with BFV conventional weapons? Why or why not?

5. What tactics do you think the Red Force used in response to STINGRAY? (in Red Defend and Red Attack missions)

6. Do you think STINGRAY would be effective on any other types of combat vehicles (e.g., tanks, wheeled vehicles, air defense systems)?

7. Are there any effects of the environment on the effective use of STINGRAY? (e.g., weather, terrain, day/night operations)

8. What do you like best and least about the STINGRAY system?

9. What changes would you recommend for future development?

10. How effective do you think STINGRAY would be in an actual battle?
(with its full capabilities and intended functions)

11. Do you think the Army should buy the STINGRAY system?

ANY OTHER GENERAL COMMENTS OR SUGGESTIONS:

APPENDIX B

DETAILED RESULTS

TABLE

Table B-1. Test mission matrix.

CREW	MISSION TYPE	BASELINE	STINGRAY MODE OF OPERATION Auto	Semi	Manual
1	Attack	28, 64	50	49, 63	--
	Defend	17	33, 41, 48	32, 40	21
2	Attack	29, 57	30, 61	60	52
	Defend	42	22, 36	23, <u>37</u>	35
3	Attack	62	56	31, 55	--
	Defend	20	15	24, <u>45</u>	34, <u>38</u>, <u>46</u>
4	Attack	54	51	58	59
	Defend	18, <u>47</u>	25, <u>39</u>	26, 44	16, 43

KEY: Each mission in the test was numbered in consecutive order. Each number presented in this table represents a single record mission completed by the designated crew. For example, Crew 1 operated Stingray in the automatic mode for three defend missions (Nos. 33, 41, 48).

NOTE: A total of 64 missions were completed, with missions 1-14 representing pilot missions (not reported here). Missions 19 and 53 were aborted and Mission 27 was conducted at night. No data from these three missions were used in the analyses. Workload ratings were not obtained for 6 missions (those underlined in the table). Therefore, workload data was collected and analyzed for a total of 41 missions.

Due to the requirements of the test board and realities of field testing, it was impossible to plan and achieve a complete counterbalanced design. Therefore, every effort was made to rotate the crews through the various mission conditions without systematic bias. All crews participated at least once in every mission condition, except for two crews who did not operate Stingray in the manual mode for an attack mission.

Table B-2. ANOVA table for TLX real-time workload data.

Source	df	SS	F
Between Subjects (S)			
Position (P)	1	3428.85	.65
P [crew]	6	31805.65	
Within subjects			
Mission type (MT)	1	1518.42	1.64
MT x S	7	6486.69	
Mode (M)	3	10178.05	2.83*
M x S	21	25133.81	
Task (T)	5	3867.67	1.65
T x S	35	16427.42	
MT x M	3	2676.10	3.20**
MT x M x S	17	4745.77	
MT x T	5	429.22	1.39
MT x T x S	35	2161.69	
M x T	15	1027.86	1.42
M x T x S	103	4981.53	
MT x M x T	15	818.29	1.03
MT x M x T x S	83	4376.10	

NOTE: The second factor for each successive pair of factors is the error term used to determine the F-ratio for the first factor. For example, P[crew] is the between subjects error term for the factor of crew member postion and MT x S is the within subjects error term for the factor of mission type. Since there are unequal numbers of observations for different combinations of test conditions, a general procedure for calculating an analysis of variance is inappropriate. The analysis summarized in this table was derived using the general linear model procedure given in Chapter 20 of the SAS User's Guide: Statistics, Version 5 (1985, Cary, NC: SAS Institute, Inc). This procedure subtracts
degrees of freedom from the error term, where appropriate (e.g., for Crews 1 and 3 on Stingray-manual attack missions), to compensate for missing data.

The Probability of an F-ratio larger than the one obtained, given the degrees shown, was greater than 0.15 except where designated: * p=0.063, ** p=0.050.

Table B-3. Mean real-time TLX workload ratings for target acquisition tasks.

TASK	MISSION TYPE	BASELINE	STINGRAY MODE OF OPERATION Auto	Semi	Manual
Search	Attack	38	22	36	67
	Defend	40	22	36	39
Detect	Attack	38	22	38	66
	Defend	37	22	30	34
Locate	Attack	36	24	30	64
	Defend	40	21	31	34
ID	Attack	32	23	29	53
	Defend	28	19	25	26
Classify	Attack	30	25	32	52
	Defend	34	21	28	30
Target Handoff	Attack	28	24	30	48
	Defend	31	22	29	33

NOTE: Greater values indicate increased workload (range 0 - 100).
Workload ratings are averaged across crews (BCs and gunners).

Table B-4. Mean real-time TLX workload ratings by crew position.

MISSION TYPE	CREW POSITION	BASELINE	STINGRAY MODE OF OPERATION		
			Auto	Semi	Manual
Attack	BC	29	20	31	56
	Gunner	38	26	34	61
Defend	BC	27	22	29	30
	Gunner	44	20	30	35

NOTE: Greater values indicate increased workload (range 0 - 100).
Workload ratings are averaged across the four BCs and four gunners for all six target acquisition tasks.

Table B-5. Mean real-time TLX workload ratings for subscale dimensions.

TASK	MODE OF OPERATION	SUBSCALE DIMENSION MEN	PHY	TEM	PER	EFF	FRU
SEARCH	Baseline	39	36	42	28	54	38
	ST-auto	20	20	25	15	29	23
	ST-semi	39	27	39	34	46	39
	ST-manual	46	40	49	42	58	49
DETECT	Baseline	38	33	43	28	53	36
	ST-auto	21	18	26	16	27	24
	ST-semi	34	29	31	30	43	40
	ST-manual	44	37	47	36	55	46
LOCATE	Baseline	39	33	42	30	50	37
	ST-auto	21	19	26	19	30	21
	ST-semi	34	26	34	27	43	38
	ST-manual	45	40	46	38	52	41
ID	Baseline	32	27	33	24	37	30
	ST-auto	21	18	24	17	23	19
	ST-semi	30	24	25	25	36	30
	ST-manual	39	32	37	27	45	32
CLASSIFY	Baseline	35	28	33	26	43	30
	ST-auto	24	19	25	17	28	23
	ST-semi	31	25	29	29	44	32
	ST-manual	40	37	40	32	45	37
TARGET HANDOFF	Baseline	28	24	33	28	43	27
	ST-auto	22	18	28	20	26	22
	ST-semi	29	22	31	26	41	33
	ST-manual	37	31	43	34	53	32

KEY: MEN = mental demand, PHY = physical demand, TEM = temporal demand, PER = perception of performance success, EFF = effort expended, FRU = frustration level.

NOTE: Greater values indicate increased workload (range 0 - 100). Workload ratings are averaged across crews (BCs and gunners) and mission types (attack and defend).

Table B-6. Prospective, real-time, and retrospective TLX workload ratings for each BC and gunner.

		STINGRAY MODE OF OPERATION		
POSITION	**BASELINE**	**Auto**	**Semi**	**Manual**
		ATTACK MISSION		
BC1	65 (22) 18	13 (8) 9	8 (15) 10	35 (*) 17
3	46 (42) 62	16 (19) 35	31 (48) 41	38 (75) 62
5	(18) 26	(10) 15	(32) 36	(*) 58
7	(30) 34	(45) 32	(43) 33	(36) 41
GU2	34 (24) 24	16 (21) 10	23 (21) 13	29 (*) 11
4	37 (52) 34	17 (17) 12	26 (20) 23	70 (50) 18
6	(30) 35	(34) 33	(47) 35	(*) 38
8	(48) 62	(46) 41	(49) 56	(72) 50
		DEFEND MISSION		
BC1	(43) 15	(19) 10	(28) 9	(37) 14
3	(28) 46	(23) 24	(40) 28	(46) 46
5	32 (10) 19	10 (17) 14	63 (12) 17	45 (14) 12
7	57 (26) 25	36 (37) 24	50 (34) 27	63 (30) 27
GU2	(31) 26	(12) 14	(11) 14	(16) 15
4	(56) 28	(12) 9	(22) 21	(36) 30
6	51 (48) 26	40 (50) 29	57 (43) 29	72 (35) 29
8	21 (40) 51	11 (32) 32	21 (47) 43	28 (44) 43

* = missing data

KEY: P (RT) R , where P = prospective ratings, (RT) = real-time ratings, and R = retrospective ratings.

NOTE: The TLX workload ratings are averaged across six target acquisition tasks. For the prospective scales, half of the crewmembers rated attack and half rated defend missions only. This was done to reduce the number of ratings elicited, since prospective ratings were to include both day and night missions. However, only daytime mission ratings are included in the data presented in this report.

Table B-7. Mean prospective and retrospective SWORD workload ratings by task.

TASK	MISSION TYPE		BASELINE	STINGRAY MODE OF OPERATION Auto	Semi	Manual
SEARCH	Attack	P	.46	.09	.12	.33
		R	.26	.10	.16	.48
	Defend	P	.43	.09	.10	.38
		R	.33	.12	.17	.38
DETECT	Attack	P	.42	.12	.11	.35
		R	.29	.09	.17	.45
	Defend	P	.47	.12	.11	.30
		R	.22	.10	.17	.51
LOCATE	Attack	P	.42	.12	.11	.35
		R	.32	.10	.16	.42
	Defend	P	.47	.12	.11	.30
		R	.31	.10	.16	.43
ID	Attack	P	.42	.12	.11	.35
		R	.25	.15	.21	.39
	Defend	P	.47	.12	.11	.30
		R	.28	.16	.20	.36
CLASSIFY	Attack	P	.33	.18	.15	.34
		R	.27	.15	.20	.38
	Defend	P	.37	.19	.14	.30
		R	.29	.14	.20	.37
TARGET HANDOFF	Attack	R	.23	.17	.20	.40
	Defend	R	.23	.17	.20	.40
PMCS		R	.19	.27	.27	.27
COMMO		R	.12	.23	.25	.40
LAND NAVIGATION		R	.16	.25	.29	.31

KEY: P = prospective SWORD ratings, R = retrospective SWORD ratings. No prospective ratings were obtained for the TARGET HANDOFF, PMCS, COMMO, AND LAND NAVIGATION tasks.

NOTE: Greater values indicate greater proportion of workload relative to other modes in same row. Values are averaged across BCs and gunners. For prospective ratings, the tasks of LOCATE, ID, and CLASSIFY were combined into one category called, ACQUIRE TARGETS. The ratings for ACQUIRE TARGETS were allocated to these three tasks for comparison with real-time TLX ratings.

Table B-8. Mean prospective, real-time, and retrospective TLX workload ratings by mission type and mode of operation.

MISSION TYPE	RATING	BASELINE	STINGRAY MODE OF OPERATION Auto	Semi	Manual
Attack	PRO-TLX	46	15	22	43
	RT-TLX	34	23	33	58
	RET-TLX	37	23	31	40
Defend	PRO-TLX	40	24	48	52
	RT-TLX	35	21	30	33
	RET-TLX	29	19	23	27

KEY: PRO-TLX = prospective TLX ratings, RT-TLX = real-time TLX ratings, and RET-TLX = retrospective TLX ratings.

NOTE: TLX ratings are averaged across crews (BCs and gunners) for six target acquisition tasks. Greater values indicate increased workload (range = 0 - 100).

Table B-9. Mean prospective and retrospective SWORD ratings and real-time TLX workload ratings by mission type and mode of operation.

MISSION TYPE	RATING	BASELINE	STINGRAY MODE OF OPERATION		
			Auto	Semi	Manual
Attack	PRO-SWORD	.40	.13	.13	.34
	NRT-TLX	.23	.15	.22	.40
	RET-SWORD	.31	.12	.17	.40
Defend	PRO-SWORD	.42	.13	.12	.33
	NRT-TLX	.29	.13	.25	.28
	RET-SWORD	.33	.12	.17	.38

KEY: PRO-SWORD = prospective SWORD ratings, NRT-TLX = normalized Real-Time TLX ratings, RET-SWORD = retrospective SWORD ratings.

NOTE: The workload ratings from the TLX absolute scale were converted to normalized (or proportional) values for comparison with the ratings from the SWORD relative scale. Values in the table should be compared only to other values in the same row. These values are averaged over crews (BCs and gunners) and the target acquisition tasks for the four modes of operation within each mission type. They show the proportion of workload experienced for each mode of operation relative to the other three modes of operaion.

For example, the four PRO-SWORD values shown for attack missions indicate that there is proportionally more workload experienced in the baseline condition (.40) than in the Stingray-manual condition (.34) and that there was proportionaly more workload experienced for these two conditions together (.74) than for the Stingray-automatic and Stingray-semiautomatic conditions (.13 each).

Table B-10. Retrospective SWORD workload ratings and analyses for PMCS, communications, and land navigation tasks.

TASK: Preventive maintenance, checks, & service (PMCS)
($F(3,21) = 1.27$, $p > .33$)

A (.27)	M (.27)	S (.27)	B (.19)

TASK: Communications (Commo)
($F(3,21) = 5.43$, $p < .01$)

M (.40)	S (.25)	A (.23)	B (.12)

TASK: Land Navigation
($F(3,21) = 8.82$, $p < .001$)

M (.31)	S (.29)	A (.25)	B (.16)

KEY: For mode of operation, A = Stingray-automatic, S = Stingray-semiautomatic, M = Stingray-manual, B = Baseline

NOTE: Retrospective SWORD values are averaged over BCs and gunners. Means sharing the same horizontal bar are not significantly different from each other.

APPENDIX C

VERBATIM RESPONSES OF PARTICIPANTS TO THE STINGRAY END-OF-TEST QUESTIONNAIRE

On the day following the last test mission, the four Stingray test crews, their platoon sergeant, and platoon leader filled out the end-of-test questionnaire. In addition, the troop commander completed an abbreviated version of the questionnaire primarily covering tactics, safety, and general Stingray issues. Their responses are presented verbatim in the following appendix.

The respondents have been coded as follows:

BC = Bradley commander
GU = gunner
DR = driver
PLT LDR = platoon leader
PLT SGT = platoon Sergeant
CO = troop commander

Crew 1 consisted of BC1, GU2, and DR31*
Crew 2 consisted of BC3, GU4, and DR32
Crew 3 consisted of BC5, GU6, and DR33
Crew 4 consisted of BC7, GU8, and DR34

* When it became apparent in the test that an experienced driver was a necessity for effective operation of Stingray by the BC, Driver #31 became the permanent Stingray driver for all the crews. As a result, 83% of the record test missions were completed with DR31.

STINGRAY
END-OF-TEST QUESTIONNAIRE

I. TASK PERFORMANCE and WORKLOAD

1. In what ways has STINGRAY changed how you accomplish your tasks? (For example, have you dropped any less important tasks in order to accomplish STINGRAY tasks? Have other crew members picked up some of the tasks you normally do?)

BC 1: No. First the STINGRAY gives us something we never had (i.e., range to target) this is especially helpful in killing targets. Knowing when to fire and plot grid coordinates to targets. It also tells the gunner where the next target is in azimuth and mils.

BC 3: BC has picked additional tasks to what he already does. While it helps the gunner locate targets.

BC 5: yes, gunner has identified targets and engaged without myself.

BC 7: in the offense yes-the workload is harder because of control of the vehicle-my driver and I did not operate good together due to STINGRAY-I could not guide him myself. Although harder it is not impossible.

GU 2: gunner must totally control turret and weapons systems, and solely visual ID targets

GU 4: I was scanning out of my sector so STINGRAY had full view. (NOTE: STINGRAY search sector is aligned with gun LOS, so gunner would traverse turret to orient STINGRAY towards targets which were threats to rest of Blue Force)

GU 6: the task of target hand-off has basically been nullified. The gunner makes the majority of decisions in target engagement.

GU 8: There is not as many target handoffs between gunner/BC, because the range and azimuth is given.

DR 31: As main driver of the STINGRAY, I had a chance to see and hear four different crews in action. On only one crew did I see a extremely drastic drop in tasks performed. They almost eliminated fire commands and spot reports while operating STINGRAY.

DR 33: no

2. Do you think the principal operation of STINGRAY should be in the BC's station (as it was tested) or should it be moved to another crew member's (e.g., gunner)? Why or why not?

BC 1: no. It should stay at the BC position. This way the gunner has less work load to worry about and can concentrate more on gunning.

BC 3: In the BCs position because controls the vehicle, while the gunner handles gunning.

BC 5: no

BC 7: It should stay the same, I would rather want my gunner concentrating on hard target engagements than STINGRAY engagements.

GU 2: BCs station

GU 4: should be moved to gunner, BC needs to navigate and know where he is all the time to send spot reports. Gunner should have control of STINGRAY to lase all targets and any immediate danger distroy them on spot while BC is sending up grid

GU 6: I think on the offensive, the gunner should have counter-measure capabilities. The majority of the time gunner picked up targets first, also makes BC job easier.

GU 8: It should stay in BC station due to that the BC is trained more than most gunners. But certain switches and components should be more accessible by the gunner.

DR 31: It should be in control of the BC because he is in over-all control of the vehicle and a weapon like this should be in the hands of the BC not his subordinates.

DR 32: it should be in the BC's station.

DR 33: stay wear it is

DR 34: it should stay with BC because gunner is constantly scanning & firing.

3. **How often did STINGRAY pick up targets that you had not already detected by other means (e.g., ISU, reports from others in the force)?**

a) Auto mode

never 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 very often

BC 1:	5.5
BC 3:	6.5
BC 5:	6.0
BC 7:	6.0
GU 2:	5.5
GU 4:	6.5
GU 6:	3.5
GU 8:	6.5

b) Semi-auto mode

never 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 very often

BC 1:	5.5
BC 3:	4.5
BC 5:	6.0
BC 7:	6.0
GU 2:	4.5
GU 4:	5.5
GU 6:	3.5
GU 8:	4.5

c) Manual mode

never 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 very often

BC 1:*	4.5
BC 3:	2.5
BC 5:	3.0
BC 7:	0
GU 2:	1.5
GU 4:	3.5
GU 6:	2.5
GU 8:	2.5

(*BC 1: on the move 2.5)

4. How useful was the range/azimuth information displayed by STINGRAY to you in engaging targets with BFV conventional weapons?

	1	2	3	4	5	6	7	
no difference from baseline missions	¦ _____	¦ _____	¦ _____	¦ _____	¦ _____	¦ _____	¦	**very useful**

BC 1:	6.5
BC 3:	4.5
BC 5:	2.0
BC 7:	4.0
GU 2:	5.5
GU 4:	6.5
GU 6:	4.5
GU 8:	6.5

5. What percentage of the time is the BC commanding out of the hatch?

a) on the attack _____%

BC 1:	75	GU 2:	80
BC 3:	90	GU 4:	100
BC 5:	99	GU 6:	80
BC 7:	99	GU 8:	90

b) on the defense _____%

BC 1:	50	GU 2:	30
BC 3:	30	GU 4:	60
BC 5:	3	GU 6:	50
BC 7:	75	GU 8:	75

6. What percentage of the time are you looking through BFV optical sights?

a) on the attack _____%

BC 1:	40	GU 2:	99
BC 3:	20	GU 4:	100
BC 5:	3	GU 6:	100
BC 7:	1	GU 8:	80

b) on the defense _____%

BC 1:	70	GU 2:	100
BC 3:	80	GU 4:	100
BC 5:	75	GU 6:	90
BC 7:	25	GU 8:	75

7. **Do you think STINGRAY affected your performance during the missions?**

Give a number on a scale of -10 to + 10, where
-10 = greatly reduced my performance
0 = made no difference in my performance
+10 = greatly improved my performance

(a) Overall Performance of My Duty Position:

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	GU2	GU4	GU6	GU7
Automatic	Attack	+10	+8	+10	+2	+6	+10	-2	+8
	Defend	+10	+7	+10	+10	+8	+10	+5	+9
Semiautomatic	Attack	+8	+2	-10	0	+4	+10	-2	+5
	Defend	+10	+6	+10	+7	+6	+10	+5	+9
Manual	Attack	+2	-8	-10	-10	+1	0	-2	+1
	Defend	+6	-5	+10	-5	+2	+10	+5	+9

COMMENT: GU6: On offense goggles irritating, more time in defense to engage.

(b) Search for Targets:

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	GU2	GU4	GU6	GU7
Automatic	Attack	+10	+2	+10	+3	+7	+10	0	+5
	Defend	+10	+3	+10	+10	+8	+10	0	+2
Semiautomatic	Attack	+8	+7	-10	0	+4	+10	0	+3
	Defend	+10	+8	+10	+7	+6	+10	0	+2
Manual	Attack	+2	+1	-10	-10	0	0	0	0
	Defend	+5	+2	+10	-3	+2	+10	0	+2

COMMENT: GU4: Stingray anual helps only as a second pair of eyes.

7. **(Con't) Do you think STINGRAY affected your performance during the missions?**

Give a number on a scale of -10 to + 10, where
-10 = greatly reduced my performance
0 = made no difference in my performance
+10 = greatly improved my performance

(c) Detcetion (Discovery of Targets):

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	GU2	GU4	GU6	GU7
Automatic	Attack	+10	+8	+10	+2	+8	+10	0	+5
	Defend	+10	+8	+10	+8	+9	+10	+2	+1
Semiautomatic	Attack	+10	+7	-10	0	+6	+10	0	0
	Defend	+10	+8	+10	+7	+7	+10	+2	+1
Manual	Attack	+3	+2	-10	-10	+1	0	0	0
	Defend	+6	+5	+10	0	+1	+10	0	+1

COMMENT: GU4: Stingray manual helps only as a second pair of eyes.
GU6: Pick up targets quicker than Stingray.

(d) Location (Determine Target Position):

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	G2	G4	G6	G7
Automatic	Attack	+10	0	+10	0	+5	+10	+2	+4
	Defend	+10	0	+10	+10	+8	+10	+2	+1
Semiautomatic	Attack	+10	+8	-10	0	+1	+10	+2	+1
	Defend	+10	+8	+10	+9	+6	+10	+2	+1
Manual	Attack	+2	+3	-10	-7	0	0	0	0
	Defend	+5	+5	+10	0	+1	+10	0	0

COMMENT: GU6: Having Stingray give range is big asset.

7. **(Con't) Do you think STINGRAY affected your performance during the missions?**

Give a number on a scale of -10 to + 10, where
-10 = greatly reduced my performance
0 = made no difference in my performance
+10 = greatly improved my performance

(e) Classification (Prioritize Targets):

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	GU2	GU4	GU6	GU7
Automatic	Attack	+8	-3	+10	0	+2	0	0	0
	Defend	+9	-2	+10	0	+3	0	0	0
Semiautomatic	Attack	+9	+6	-10	0	+1	0	0	0
	Defend	+9	+7	+10	0	+2	0	0	0
Manual	Attack	+5	+3	-10	0	0	0	0	0
	Defend	+6	+5	+10	0	0	0	0	0

COMMENT: BC7: No challenge, there were two types of vehicles: tank/Bradley easily classified.
GU4: Stingray does not show what type of vehicle it is.

(f) Identification (Recognize Target Type):

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	GU2	GU4	GU6	GU7
Automatic	Attack	+8	0	0	0	0	0	0	0
	Defend	+9	0	0	0	0	0	0	0
Semiautomatic	Attack	+9	+7	0	0	0	0	0	0
	Defend	+10	+8	0	0	0	0	0	0
Manual	Attack	+4	+3	0	0	0	0	0	0
	Defend	+6	+5	0	0	0	0	0	0

COMMENT: BC7: No challenge, there were two types of vehicles: tank/Bradley easily classified.
GU2: Stingray does not identify target type.
GU4: Stingray does not show what type of vehicle it is.

7. **(Con't) Do you think STINGRAY affected your performance during the missions?**

Give a number on a scale of -10 to + 10, where
-10 = greatly reduced my performance
0 = made no difference in my performance
+10 = greatly improved my performance

(g) Target Handoff:

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	GU2	GU4	GU6	GU7
Automatic	Attack	+6	+3	0	0	+3	+10	+1	+5
	Defend	+8	+5	0	+5	+4	+10	0	0
Semiautomatic	Attack	+6	+2	-10	0	+2	+10	+1	+3
	Defend	+8	+3	-10	+3	+3	+10	0	0
Manual	Attack	+2	+1	-10	0	0	+10	0	0
	Defend	+4	+3	-10	-2	+1	+10	0	0

COMMENT: BC7: Most of the tir..: my gunner ID targets before Stingray in the offense.

(h) Employ BFV Weapon Systems:

MODE	MISSION	TEST PERSONNEL							
		BC1	BC3	BC5	BC7	GU2	GU4	GU6	GU7
Automatic	Attack	+10	0	+10	0	0	+10	+2	+7
	Defend	+10	0	+10	-2	0	+10	+2	+10
Semiautomatic	Attack	+9	+6	0	0	0	+10	+2	+4
	Defend	+10	+8	+10	-2	0	+10	+2	+7
Manual	Attack	+5	+3	0	0	0	0	0	+1
	Defend	+5	+5	0	-2	0	0	0	+5

COMMENT: BC7: Because of the low position of the laser you have to sit higher on a berm for it to scan; you're exposed more because of it.
GU6: Range helps gunner engage targets with better first round hit probabilities.

7. **(Con't) Do you think STINGRAY affected your performance during the missions?**

Give a number on a scale of -10 to + 10, where
-10 = greatly reduced my performance
0 = made no difference in my performance
+10 = greatly improved my performance

(i) COMMO:

MODE	MISSION	TEST PERSONNEL			
		BC1	BC3	BC5	BC7
Automatic	Attack	+10	-3	-10	-4
	Defend	+10	-2	-10	-1
Semiautomatic	Attack	+8	-6	-10	-4
	Defend	+9	-4	-10	-1
Manual	Attack	+3	-9	-10	-4
	Defend	+5	-6	-10	-1

COMMENT: Commo was bad. We had to hold the hand mike inside the CVC.

(j) Land Navigation:

MODE	MISSION	TEST PERSONNEL			
		BC1	BC3	BC5	BC7
Automatic	Attack	+10	0	0	0
	Defend	+10	0	0	0
Semiautomatic	Attack	+9	-5	-10	-5
	Defend	+10	0	0	0
Manual	Attack	+1	-10	-10	-10
	Defend	+8	0	0	0

Comment: BC7: It's hard to control the driver when you're in the turret.

7. (Con't) Do you think STINGRAY affected your performance during the missions?

Give a number on a scale of -10 to + 10, where
-10 = greatly reduced my performance
0 = made no difference in my performance
+10 = greatly improved my performance

(k) Command and Control:

MODE	MISSION	TEST PERSONNEL			
		BC1	BC3	BC5	BC7
Automatic	Attack	+8	0	0	0
	Defend	+10	0	0	+3
Semiautomatic	Attack	+8	-2	-10	0
	Defend	+8	-2	0	+3
Manual	Attack	+1	-5	-10	-1
	Defend	+4	-3	0	0

II. SAFETY

1. Does STINGRAY pose any particular health or safety hazards to user personnel?

CO: no I don't think so but fratricide is a definite factor to be considered

PL LDR: no

PL SGT: no if used properly

BC 1: no

BC 3: yes, the goggles is used for safety, but during night missions its hard to navigate with goggles

BC 5: --

BC 7: no

GU 2: yes, burn your eyeballs

GU 4: no

GU 6: no

GU 8: no

DR 31: only accidental laser beam firing

DR 32: it can cause blindness with carelessness of crew.

DR 33: no

DR 34: only at night because it is extremely difficult to see

2. **How concerned were you about your own health and safety whenever you were in close proximity to the STINGRAY vehicle?**

a) during the conduct of this test

not concerned at all 1 ¦ _____ 2 ¦ _____ 3 ¦ _____ 4 ¦ _____ 5 ¦ _____ 6 ¦ _____ 7 ¦ **very concerned**

CO:	2.5
PLT LDR:	1.5
PLT SGT:*	3.5
BC 1:	2.5
BC 3:	5.5
BC 5:	1.5
BC 7:	4.0
GU 2:	1.5
GU 4:	2.5
GU 6:	2.5
GU 8:	5.5
DR 33:	1.5
DR 32:	6.5
DR 31:	2.0
DR 34:**	2.5

* PLT SGT: concerned enough not to take off my eye protection

** DR 34: only at night

b) during an actual battle with STINGRAY at its full capabilities (e.g., accidents, fratricide)

not concerned at all 1 ¦ _____ 2 ¦ _____ 3 ¦ _____ 4 ¦ _____ 5 ¦ _____ 6 ¦ _____ 7 ¦ **very concerned**

CO:	5.5
PLT LDR:	2.5
PLT SGT:	6.5
BC 1:	3.5
BC 3:	4.5
BC 5:	6.5
BC 7:*	6.0
GU 2:	1.5
GU 4:	2.5
GU 6:	2.5
GU 8:	3.5
DR 33:	1.5
DR 32:	6.5
DR 31:	4.0
DR 34:*	2.5

* BC 7 & DR 34: only at night

3. Do you feel the safety procedures utilized during this test need any improvement? If so, then please explain.

CO: No, but a <u>full explanation</u> of what <u>the system tested</u> can do (safety wise) needs to be better explained to ALL participants.
PLT LDR: no. no injuries = effective safety program
PLT SGT: --
BC 1: no
BC 3: no
BC 5: --
BC 7: no night time exercises due to the goggles, I thought it was very unsafe
GU 2: no
GU 4: no
GU 6: no
GU 8: no
DR 31: safety procedures were very good during this test and also they were never any incidents of failure to follow safety precaution due to the fact of laser beam weapons.
DR 32: no
DR 33: no

- -

III. TRAINING

1. How would you rate the training you received on STINGRAY operations?

poor 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 **excellent**

PLT LDR:	5.5
PLT SGT:	5.5
BC 1:	5.5
BC 3:	5.5
BC 5:	6.5
BC 7:	4.0
GU 2:	6.5
GU 4:	6.5
GU 6:	4.5
GU 8:	5.5
DR 31:	6.0
DR 32:	4.5
DR 33:	6.5
DR 34:	3.5

2. How would you rate the STINGRAY operator's manual?

	1	**2**	**3**	**4**	**5**	**6**	**7**	
Poor								**Excellent**

PLT LDR:	4.5
PLT SGT:	6.5
BC 1:	5.5
BC 3:	1.5
BC 5:	4.5
BC 7:	6.0
GU 2:	6.5
GU 4:	1.5
GU 6:	4.5
GU 8:	6.5
DR 31:	7.0
DR 32:	4.5
DR 33:	5.5
DR 34:	5.5

3. How useful was the condensed version of STINGRAY operator's manual?

	1	**2**	**3**	**4**	**5**	**6**	**7**	
no help at all								**very useful**

PLT LDR:	4.5
PLT SGT:	6.5
BC 1:	5.5
BC 3:	3.5
BC 5:	4.5
BC 7:	7.0
GU 2:	6.5
GU 4:	6.5
GU 6:	4.5
GU 8:	6.5
DR 31:	5.0
DR 32:	4.5
DR 33:	4.5
DR 34:	6.5

4. Do you have any comments or suggestions about how to improve the STINGRAY training for future crews?

PLT LDR: no

PLT SGT: more time on STINGRAY operations, hands on training with knowledgeable personnel prior to using

BC 1: no

BC 3: yes, cut out the specific details and get straight to the point

BC 5: don't hold information back. Let them know the system. (NOTE: BC explained upon further questioning that he wants to know exactly how the STINGRAY system (laser functioning, etc) works, he is especially concerned in regards to the maintenance that would be required on the STINGRAY system. He said he watched the contractor replace components without explanation to the crews and BC wants to know everything about the system he is operating.)

BC 7: more hands on prior to actual exercises

GU 2: yes, use the four STINGRAY crews from this test as instructors for future crews because we have had hands on experience

GU 4: for gunner instead of goggle use a protective lens placed in the dust cover of ISU

GU 6: no

GU 8: no

DR 31: Power up/reset/power down procedures should be practiced more to insure user faith in using the weapon system.

DR 32: no

DR 33: no

5. If you were to pass along any tips about STINGRAY operations/functions, what would they be?

PLT LDR: none. I found the STINGRAY very straightforward.

PLT SGT: --

BC 1: Not to depend solely on STINGRAY for protection. It is a very useful system, but sometimes crews start to depend solely on STINGRAY.

BC 3: be flexible

BC 5: in offense engagements don't use semi or manual.

BC 7: watch vehicle position (level vehicle) in manual, if your gunner picks up a target hit stop scan and the laser will line up to the gun then laze away!

GU 2: utilize auto-mode more often

GU 4: If on STINGRAY scan out of your sector to acquire targets for all instead of just yourself.

GU 6: not to rely on STINGRAY too much. Often the individual will detect target first.

GU 8: already answered before (NOTE: check the HFEA questionnaire)

DR 31: learn to use the STINGRAY <u>along</u> with present procedures instead of dropping procedures to use the Stingray! (NOTE: when asked, driver said tasks dropped included things such as spot reports, fire commands).

DR 33: it helps to detect targets well

6. **Do you feel that personnel need any additional/specific skills or aptitudes to effectively operate STINGRAY (other than what is currently required for your MOS)?**

PLT LDR: no

PLT SGT: --

BC 1: no it is an easy system to operate.

BC 3: no

BC 5: know how to deploy STINGRAY effectively.

BC 7: just more patience

GU 2: no

GU 4: no

GU 6: no

GU 8: yes, need to learn about lasers and STINGRAY capabilities. (NOTE: GU explained that this info would help to understand how to operate the system better, they just don't want to know "push this button" level of info)

DR 31: none that I can think of now

DR 33: no

IV. PERFORMANCE

1. In general, the survivability of the Blue Force was due to

BLUE ATTACK	BLUE DEFEND	
_______%	_______%	presence/absence of STINGRAY
_______%	_______%	tactics employed
_______%	_______%	personnel
_______%	_______%	instrumentation (e.g., MILES)
_______%	_______%	other _____________

NOTE: these should add up to 100%

CO:			PL LDR:			PL SGT:		
	20	50		20	30		20	30
	40	25		40	30		60	50
	40	25		40	40		5	5
	-	-		-	-		15	15
	-	-		-	-		-	-

BC 1:			BC 3:			BC 5:			BC 7:		
	30	0		30	30		50	80		30	35
	20	50		30	10		20	10		40	40
	40	40		10	30		20	5		25	25
	10	10		30	30		10	5		0	0
	0	0		0	0		0	0		5	5

GU 2:			GU 4:			GU 6:			GU 8:		
	25	50		50	60		15	25		50	75
	25	10		5	5		45	35		37	12
	50	40		5	5		25	25		10	10
	0	0		40	30		15	15		2	2
	0	0		0	0		0	0		1	1

DR 34:			DR 32:			DR 33:			DR 31:		
	10	50		60	40		10	50		25	40
	70	20		40	60		20	10		30	25
	5	15		50	50		30	10		15	10
	15	15		50	50		10	10		0	0
	0	0		0	0		30	20		30	25

* GU 8 and DR 31: other = terrain

2. How would you tactically deploy STINGRAY on the defense and attack? Please include your recommendations for where to position it in the formation, how many STINGRAYs should be in a platoon or company, what mode (Auto, Semi, Manual) of operation(s) would be best, should STINGRAY be in the Platoon Leader's, Sergeant's or Company Commander's vehicle?

a) on the defense:

CO: use at the flanks at least one per platoon, interlocking fields of fire, semi auto or auto mode best to ID friend or foe

PLT LDR: use in auto forward. drop back to defensive belt & switch to semi-auto to avoid fratricide. Do not put on key leaders vehicle. Use St mostly for target acquisition & to enhance spot reporting.

PLT SGT: position the STINGRAY with the best field of fire near the defending force but not to close enough to enable the enemy to engage it with the defending force. A dismounted mode would be ideal for better concealment. The defending vehicles would be the priority targets for the enemy not the St vehicle which in its current form is easily identified at great distances.

BC 1: first, two STINGRAY to a platoon, put on the section leaders tracks. The formation for defense would be:

STINGRAY wingman PLdr PlSgt wingman STINGRAY

with the field of view and regard the STINGRAY can cover the flanks plus crossfire across the center sector.

BC 3: in the center on semi with tanks. It would be a squad leader in the position.

BC 5: system works for himself

BC 7: STINGRAY should be placed center sector to defend the whole sector if a force should come. Srong East West North South it should dictate were STINGRAY is places [sic].

GU 2: STINGRAY center sector, 1/platoon, auto mode, Plt SGT

GU 4: STINGRAY in center sector

GU 6: Have 2 per platoon, have one cover frontal area, other covers a vulnerable flank

GU 8: Platoon's Sergeants position, one per platoon. And maybe use it in center sector to cover the whole platoon.

DR 31: normal employment of STINGRAY during defend missions

DR 33: in the middle so it could protect more or less the whole plt, troop, etc and not just the left or right side

DR 32: STINGRAY should be in the middle. The Company should have one STINGRAY per platoon. The mode of Defense should be auto. The Platoon Ldr should have the STINGRAY.

DR 34: Stingray should be placed in the rear of the defense to provide maximum usage. There should be one, maybe two, STINGRAY in the defense depending on how large an area is defended and how many enemy are expected. Auto should be used unless forward elements are required to fall back.

2. (Con't) How would you tactically deploy STINGRAY on the defense and attack? Please include your recommendations for where to position it in the formation, how many STINGRAYs should be operation(s) would be best, should STINGRAY be in the Platoon Leader's, Sergeant's or Company Commander's vehicle?

b) on the attack:

CO: must be on auto mode or it distracts the vehicle commander, use again on flanks, fratricide could be a problem

PLT LDR: use STINGRAY just ahead of tanks to give their firepower maximum protection and target acquisition information just before the armor punch. Then switch STINGRAY to semi-auto & place with base-of-fire element.

PLT SGT: use STINGRAY as a base of fire element either as a single vehicle or as a section. Positioned just off the axis of advance to provide better ability to detect targets. Another element used as a base of fire element from another direction.

BC 1: still two per platoon, same two vehicles. I would use the three team concept (ie., the two wingman scouts on the flanks to protect the STINGRAY from flank shots).

```
wingman                                                  wingman
      STINGRAY          PlSgt   PlLdr          STINGRAY
```

BC 3: in the center on auto with a squad leader in it

BC 5: move with others until contact, break contact get a good defensive position to lase targets

BC 7: STINGRAY should be places in a high over watch. Then while the main force move it can scan. then bound up according to terrain and attack etc. it should not be forward.

GU 2: STINGRAY in center back, auto mode, Plt SGT

GU 4: wedge formation, STINGRAY in middle (point vehicle)

GU 6: have 2 per platoon, place one with each scout section. Get rid of semi.

GU 8: one per platoon, platoon sergeants vehicle and use in overwatch position center sector.

DR 31: it should be positioned approx 300-500 meters behind forward elements to allow its survivability but also allows STINGRAY to cover and protect those forward elements

DR 33: basically the same

DR 32: The STINGRAY should be in the middle, in the semi mode, on the Platoon Ldrs vehicle.

DR 34: STINGRAY should be kept in the center of the rear elements to be able to flow to the most heavily defended side. The STINGRAY should be used in semi-auto or manual and have only one in the attack to prevent confusing when battle is at close quarters.

2. **(Con't) How would you tactically deploy STINGRAY on the defense and attack? Please include your recommendations for where to position it in the formation, how many STINGRAYs should be operation(s) would be best, should STINGRAY be in the Platoon Leader's, Sergeant's or Company Commander's vehicle?**

c) any other comments about tactics:

CO: --
PLT SGT: --
PLT LDR: Stingray's major contribution is in target acquisition. Even without a countermeasure capability, STINGRAY will save very important combat power simply by alerting commanders to the presence, shape, and extent of a threat fire sack.

BC 1: na
BC 3: --
BC 5: --
BC 7: The PL Ldr & SGT and CO have enough to worry about, one per plt would work fine in my opinion

GU 2: no
GU 4: --
GU 6: --
GU 8: none

DR 31: please do not employ the STINGRAY on a Platoon Leader's vehicle, they have a extremely large number of tasks and adding STINGRAY would "be the straw that broke the camel's back". I believe Senior scout should operate the STINGRAY.

DR 33: should have STINGRAY one to a platoon on Plt Sgt track.

DR 34: I noticed during the last few missions that when attacking several Blue elements reached the destination and were going in circles and ended up shooting other blue elements. If the STINGRAY was on auto and Blue Forces have shutters, then half of the Blue Forces would have been blinded. While attacking the STINGRAY should be used in semi-auto or manual to prevent confusion and injury to friendly troops.

3. **How useful was the target position information relayed by the STINGRAY crew to the rest of the Blue Force?**

no difference from baseline missions	1	2	3	4	5	6	7 very useful
CO:*		2.5					
PLT LDR:					5.5		
PLT SGT:						6.5	
BC 1:						6.5	
BC 3:				4.5			
BC 5:					5.5		
BC 7:*						6.0	
GU 2:				4.5			
GU 4:						6.5	
GU 6:		2.5					
GU 8:					5.5		
DR 32:						6.5	
DR 33:					5.5		
DR 34:				4.5			
DR 31:						6.0	

* BC 7: range was good for fire control
* CO: range info good but azimuth info useless

4. Do you think STINGRAY accomplished its goal of delaying the Red Force's fire so that the Blue Force could engage the enemy with BFV conventional weapons? Why or why not?

CO: yes in the defense--good defensive weapon when tied in with other Stingrays

PLT LDR: can't tell, a good defender tries to hold his fire until you're well into the fire sack anyway

PLT SGT: yes, it provides time for Blue Force vehicles to locate and lay their weapons while Red Forces cannot use their optics

BC 1: yes, anytime we can get a 4 - 5 sec advantage, it is very helpful our vehicles were able to take on 10 enemy vehicles and accomplish the mission 80% of the time.

BC 3: yes, because it had caused shutters to close and delayed Red from engaging

BC 5: yes

BC 7: In the beginning yes but Red got smart and would not orientate until STINGRAY was killed - overall yes it did delay the Red Force - it forced them to change tactics

GU 2: yes, put out their sights

GU 4: yes

GU 6: yes

GU 8: yes, until the Red Force position to the rear until they could engage the Blue Force

DR 33: yes, they couldn't see us. plain as that.

DR 31: yes, causing the simulated blinding of optics gives Blue Force more time to engage targets. Enemy "Red Force" gunners can not kill what they can not see.

DR 32: At first it did. Because at first the Red Force must have been a little bit scared to get blind.

DR 34: Yes, because Red Force turned their turrets away until Blue was in range. It worked defensively better than offensively.

5. What tactics do you think the Red Force used in response to STINGRAY? (in Red Defend and Red Attack missions)

CO: turned sights away until enemy came close

PLT LDR: Red Defend- did not point optics at STINGRAY until they knew we were within range. Red Attack--no countermeasure for STINGRAY

PLT SGT: maintain gun orientation far enough off the target that STINGRAY would not be able to detect targets, once the commander identified targets he would lay gun on target and fire.

BC 1: it rendered their sights inoperative thus causing them to hip shot with the naked eye making it very hard to get direct hits on us.

BC 3: Red attack will probably stay the same - all out
Red defence might differ with score camouflage

BC 5: I don't think there is a tactic than can be used effectively.

GU 2: orientated gun tubes to the rear until within range, cheating by re-keying their MILES

GU 4: ?

GU 6: A couple of vehicles didn't deploy sights on the axis of advance on offense. On defense, always a vehicle that was on flank, not affected by STINGRAY.

GU 8: They positions their turrets away from the suspected position of STINGRAY.

DR 31: they would use blitz (high speed) maneuvers in an attempt to get a few of their vehicles to the objective and hopefully securing it.

DR 32: after their shutter closed they went to their back-up sight. (NOTE: the backplate which supports the surrogate target sight effectively blocks usage of the auxiliary sights on the BFVs, so this could not be the case).

DR 34: Defensively they turned their turrets away.

6. **Do you think STINGRAY would be effective on any other types of combat vehicles (e.g., tanks, wheeled vehicles, air defense systems)?**

CO: useful on tanks just as it is on a Bradley, in fact maybe more useful since enemy forces key on tanks & tank killing rather than scouts

PLT LDR: more effective on tanks for its countermeasure function. More effective on BFVs for its target detection function.

PLT SGT: wheeled vehicle for better maneuverability and easier to conceal and camouflage

BC 1: yes, tanks and humvees

BC 3: HMMV

BC 5: air defense systems

BC 7: you can make anything work

GU 2: no-STINGRAY should go with the first people to go into combat-SCOUTS!

GU 4: yes

GU 6: on light units which deploy HMMWVs

GU 8: yes, maybe helicopter, air defense, tank

DR 31: a wheel vehicle could give it a steady platform to fire along with high speed movement and stealth.

DR 32: maybe

DR 33: I think it would be good on tanks.

DR 34: I believed STINGRAY would be better on a smaller more maneuverable vehicle (hummer).

7. Are there any effects of the environment on the effective use of STINGRAY? (e.g., weather, terrain, day/night operations)

CO: in present configuration STINGRAY ineffective at night

PLT LDR: Yes. Terrain, improperly used, can completely destroy the STINGRAY advantage.

PLT SGT: night operations, laser goggles impede night vision to a point you cannot see anything

BC 1: there seem to be no real effect on the system

BC 3: night time operations if not effective enough with protective goggles

BC 5: night operations

BC 7: due to goggles it was dangerous to operate at night

GU 2: weather-rain

GU 4: no

GU 6: no

GU 8: --

DR 31: night missions with the STINGRAY with goggles is very hard and the success of Blue Force attacks were greatly reduced due to slower speeds, lack of driver's vision, and gunner's vision. (Driver added with further questioning: he couldn't see the dunes at night with little depth perception, and if STINGRAY vehicle took a dune too fast the bumping of the vehicle causes STINGRAY to have ES fails).

DR 32: The terrain can be an effect on STINGRAY.

DR 33: none that I noted

DR 34: The night operation were difficult because the night sight is green and so were the goggles.

8. What do you like best and least about the STINGRAY system?

CO: best-excellent defensive weapon & gives accurate range to target least-limitations on the move & in manual mode--it is a distractor not combat multiplier

PLT LDR: Stingray saves lives, provides excellent timely battlefield information, some countermeasure protection. Stingray is too unreliable.

PLT SGT: Its ability to detect vehicles at great distances, it picks up targets you cannot see with just your optics.

BC 1: liked-auto mode, range display, early warning at 3750m

BC 3: that it delayed Red Force and gave extra time to Blue to engage

BC 5: --

BC 7: auto mode -- manual mode is useless

GU 2: ability to wash out enemy sights

GU 4: best-it gives ranges, least-if gun is scanning left sector STINGRAY cannot scan right sector

GU 6: gives you a range and more time to engage

GU 8: once hit by STINGRAY the enemy should not be able to fire back

DR 31: I loved the STINGRAY in Auto-mode on both attack and defense missions cause it allowed the BC to give other vehicles general location of enemy forces. What I liked least is the large smoke cloud caused by constantly revving the engine. (NOTE: Driver explained that he had to rev the engine to keep the RPMs up to keep STINGRAY powered).

DR 32: Sometimes it detects targets pretty fast. Least it breaks down to much.

DR 33: I found that taching the engine out is the least. Being able to tell wear target exactly is (best).

DR 34: I don't like the goggles. (Driver added when questioned-due to worsening ability to see rather than discomfort of wear, Dr said hatch is closed all the time & he is looking through vision blocks, also night sight is green).

9. What changes would you recommend for future development?

CO: stab mode & operations at night (NOTE: stab refers to capability to stabilize Stingray as can be done for 50mm gun)

PLT LDR: Focus more on the tactical intelligence functions of the Stingray. The countermeasure is not so important.

PLT SGT: --

BC 1: move the VDU. possibly a HUDS in the CVC
BC 3: more room needed in the turret
BC 5: --
BC 7: no manual mode

GU 2: none
GU 4: have STINGRAY work independently (NOTE: of gun LOS)
GU 6: --
GU 8: --

DR 31: improved power source capabilities
DR 33: exhaust
DR 34: put on other vehicle

10. How effective do you think STINGRAY would be in an actual battle? (with its full capabilities and intended functions)

CO: very effective if by the time it was fielded the enemy didn't have a countermeasure for it

PLT LDR: very effective

PLT SGT: very effective

BC 1: very effective
BC 3: depending on time when it is used, yes
BC 5: excellent
BC 7: --

GU 2: 100% more effective in ID and killing targets
GU 4: 100%
GU 6: improve survivability by substantial margin on defense
GU 8: If the enemy is not aware of STINGRAY. It could be very devastating to the enemy.

DR 31: I think the effectiveness of the STINGRAY in actual battle would be a big combat multiplier and would increase survivability of more personnel.

DR 32: It depends on the capabilities and functions of the crew.

DR 33: unstoppable

DR 34: Defensively it would be great but offensively is questionable. It appears to be a little fragile and would be destroyed easily.

11. Do you think the Army should buy the STINGRAY system?

CO: Further tests need to be done & a consideration of the test should be how hard is is to countermeasure. Would we end up spending hundreds of thousands of dollars for a system than can be defeated with 29 cents worth of window screen?

PLT LDR: Only after we enhance its information providing capabilities (give better info on where enemy is. may a triangulation feature) & making it more reliable.

PLT SGT: yes

BC 1: yes

BC 3: yes

BC 5: if changes suggested are made

BC 7: yes

GU 2: yes

GU 4: yes

GU 6: yes

GU 8: yes, but on a limited bases until more proven by other units with other missions.

DR 33: If they get it to work properly all the time, yes.

DR 31: Yes, once the little "bugs" have been worked out.

DR 34: Yes, with a few modifications.

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ANY OTHER GENERAL COMMENTS OR SUGGESTIONS:

BC 1: The STINGRAY is a very useful weapon. Because I think not only killing enemy optics, it will play a big psychological warfare also.