Research Note 84-108

BATTERY COMPUTER SYSTEM (BCS) HUMAN FACTORS FIELD EVALUATION

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This report presents the results of a human factors evaluation of the Battery Computer System (BCS). The evaluation was part of a Follow-On Evaluation, Operational Test 706, conducted by the U.S. Army Operational Test and Evaluation Agency (OTEA) in January through March, 1982. Numerous human factors problems were identified. The results were incorporated into the OTEA final report and were used in determining what modifications were needed to the BCS before entering into full scale production.

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FOREWORD

The modern Army is in the midst of being equipped with an unprecedented amount of equipment incorporating a high degree of technological sophistication The high cost of such equipment means that it can only be procured in limited quantities, thus making it imperative that the equipment be utilized to its highest potential.

One of the factors which frequently prevents this is inadequate considerations of the man-machine interface during system design. The result is that the average soldier is precluded from effectively operating the system. In order to identify and help rectify such problems the Army Research Institute is frequently tasked by various Army organizations, such as the U.S. Army Operational Test and Evaluation Agency, to conduct human factors evaluations of selected Army equipment in an operational field test environment. The present human factors field evaluation of the Battery Computer System is one product of this effort.

The findings of this report were approved by the U.S. Army Operational Test and Evaluation Agency and integrated into the report "Battery Computer System Follow-On Evaluation (U), FTR-OT-706 (SECRET), U.S. Army Operational Test and Evaluation Agency, January 1983."

BATTERY COMPUTER SYSTEM (BCS) HUMAN FACTORS FIELD EVALUATION

EXECUTIVE SUMMARY

Requirement:

This human factors evaluation was conducted as part of the follow-on evaluation of the Battery Computer System conducted at Fort Hood, Texas in the first three months of 1982. The research was carried out in conjunction with Follow-On Evaluation (FOE), Operational Test 706, conducted by the US Army Operational Test and Evaluation Agency.

Procedure:

Questionnaires consisting of five-point rating scales were administered to soldiers in the two field artillery battalions employing the BCS. Separate questionnaires were given to Battery Computer Unit (BCU) operators, firing battery section chiefs, gunners, fire direction officers, maintainers, battery commanders, and battalion commanders, executive officers, and S3's. Areas covered in the questionnaires included the adequacy of controls and displays within the system, as well as the adequacy of the procedures used in operating the system. The questionnaire administrations were followed up with interviews in order to obtain clarification of ratings which were critical of the system.

Results:

I. Mission Performance

1. Tactical Operations. In this area the most common problem involved establishing communications with subscribers of BCS (e.g., TACFIRE, other BCS's, and FIST's) and with the gun display units. Operators of the battery computer units (BCU) need more training in dealing with communications problems. Problems also occurred in maintaining serialization of the BCU. It was not uncommon for a BCU to get out of synchronization with TACFIRE, causing a delay in the processing of fire missions until the BCU operator could get the unit back into the correct serialization position.

2. Error Handling. Some error messages were not explained in the manuals and consequently the operators could not determine their meaning.

3. Displays and Controls. Several soldiers complained that it was difficult to read either the display of the BCU or the display of the gun assembly when either of them was exposed to direct sunlight. Recommendations were made for the installation of shields to reduce light reflection off of the displays.

4. NBC Environment. The primary complaint of BCU operators while dressed in NBC protective clothing was that the clothing caused them to operate the BCU at a somewhat slower rate than normal.

II. Logistics and Maintenance

1. Built-in Test Equipment. Most operators found the built-in test equipment easy to use.

2. Manuals. Operators complained that the operators' manuals lacked indexes for assisting in locating specific information, failed to define some of the error messages that appeared on the BCU display, and needed to contain information on troubleshooting communications problems.

3. Repair and Replacement of Parts. The most troublesome repair procedure concerned the replacement of electrical cables which were bound together in bundles behind the BCS when it was mounted in an armored command vehicle. Access to the cables was extremely limited and the grouping of them into bundles appeared to serve no purpose other than to cause problems in trying to separate out a cable from the bundle when trying to replace it. An additional problem in this area concerned the amount of time required to replace computer boards in the BCU. Sometimes a given BCU would be down for several hours because of a bad computer board which had to be replaced from division level stockage. Several operators recommended that a battery level prescribed load test (PLL) be set up so that such lengthy downtimes from common board failures could be minimized.

4. Battalion level personnel expressed serious doubts that the current authorized number of maintenance personnel will be able to adequately maintain the BCS when it is fully fielded.

Utilization of Findings:

The findings were incorporated into the OTEA final report "Battery Computer System Follow-On Evaluation (U), FTR-OT-706 (SECRET), US Army Operational Test and Evaluation Agency, January 1983," and will be used in determining what modifications, if any, are needed to the BCS before entering into full scale production.

BATTERY COMPUTER SYSTEM (BCS) HUMAN FACTORS FIELD EVALUATION

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INTRODUCTION

In future armed conflicts the US Army will very possibly face an aggressor that greatly outnumbers it and is highly mobile. This will result in a situation in which there will be numerous targets that must be taken under fire, but none of which will remain stationary for very long. Being confronted with large numbers of aggressor units will require that maximum use be made of field artillery firepower. The fact that the aggressor units will be highly mobile and not remain stationary for very long will require that artillery be able to deliver accurate fire very rapidly.

The Battery Computer System (BCS) was developed in order to meet this need. The current computational capability of the artillery battery fire direction center resides in the M18 Field Artillery Digital Automatic Computer (FADAC). But FADAC has relatively slow computational speeds, needs extensive manual intervention, cannot communicate digitally with the Tactical Fire Direction System (TACFIRE) at battalion, and cannot accept fire requests from a forward observer by digital means. BCS was designed to correct these deficiencies.

In January through March of 1982 the US Army Operational Test and Evaluation Agency (OTEA) conducted an 11-week Follow-on Evaluation (FOE) of BCS at Fort Hood, Texas. Among the test objectives was a requirement to identify human factors implications resulting from the deployment of the system. The Army Research Institute (ARI) Field Unit at Fort Hood was asked by OTEA to fulfill the requirements of this test objective. The current report represents the product of that effort. The results reported here have been incorporated into, and are a part of, the OTEA Test Report.

System Description

The AN/GYK-29 Battery Computer System consists of the Battery Computer Unit (BCU), which is located in the fire direction center of an artillery battery, the power distribution unit (PDU) which supplies power to the BCU and is located adjacent to the BCU, and one Gun Display Unit (GDU) per howitzer section (up to a maximum of 12 GDU's). The BCU and GDU are shown in Figure 1.

The BCU consists of an 18 bit central processing unit, 128K bytes of random access memory, a keyboard, a plasma panel display, a program load unit, communications terminals and receptacles, and a universal mount. The volatile memory of the BCU during short periods of primary power loss can be maintained by rechargeable batteries located in the PDU. The communications terminals and receptacles of the BCU allow for either wire or radio communications through two external and one internal channel. The two external channels allow for digital as well as voice communications.

The GDU consists of one section chief's assembly (SCA), two gun assemblies (GA), and one control case which distributes power and communications to the SCA and GA's. The SCA is a small hand-held device which receives and displays all fire commands and warning signals from the BCU and

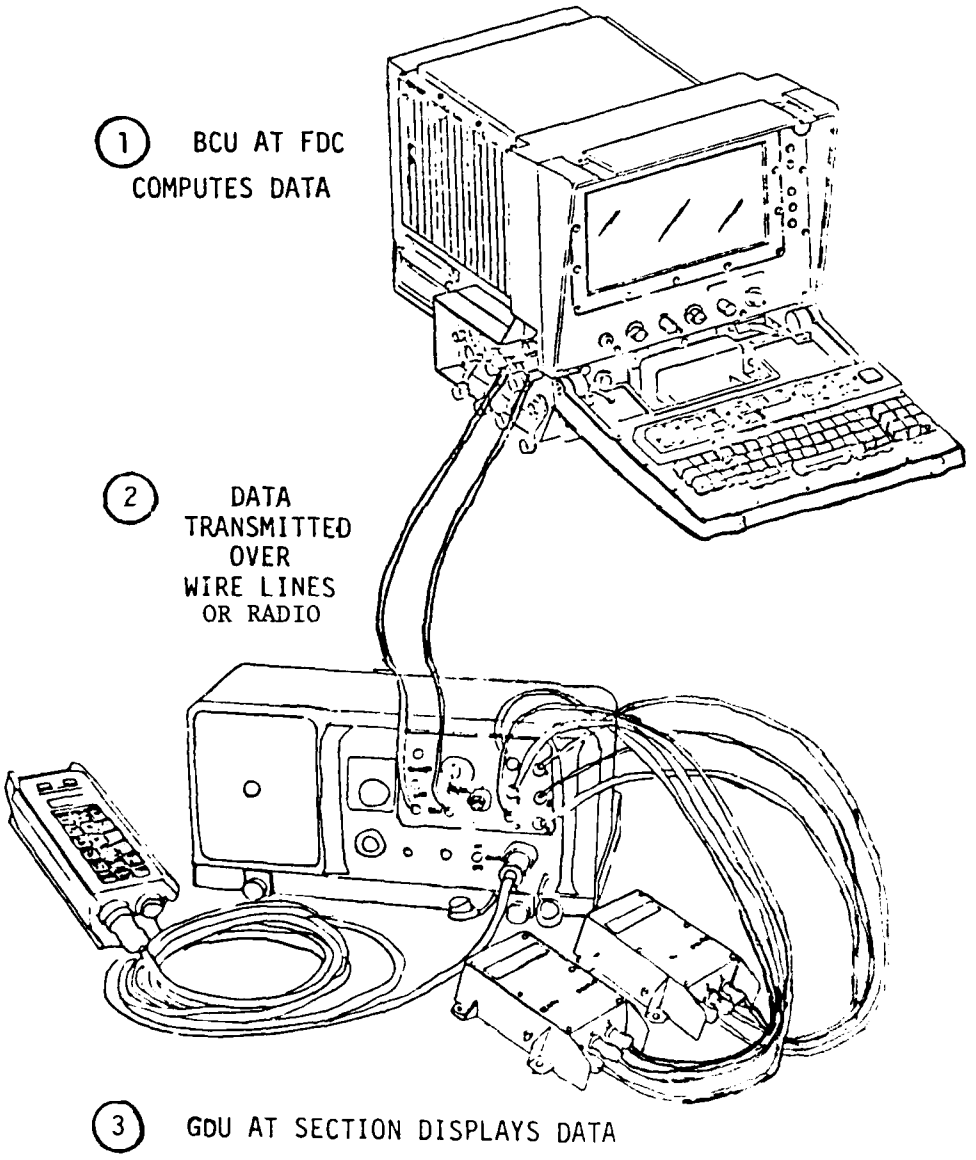


Figure 1. Basic Components of the Battery Computer System

provides necessary digital acknowledgements and status reports to the BCU. Voice communications is provided to the BCU operator using a headset connected to the SCA. The GA's are mounted on the howitzer itself near the on-carriage fire control equipment. Each GA displays either deflection or quadrant elevation.

BCS Function Within the Field Artillery Battalion

Figure 2 illustrates the function of BCS within a field artillery (FA) battalion. An FA battalion includes three batteries which have six guns each. A Fire Direction Center (FDC) for each battery receives information from two sources. In the autonomous mode, the request for fire comes directly from the Fire Support Team (FIST), either by voice or digitally using the digital message device (DMD). In the TACFIRE mode, the FIST sends its request for fire to the battalion FDC and TACFIRE allocates the fire mission to one of the batteries.

In the Battery FDC, the two soldiers interacting most with the BCU are the BCU operator (by TOE an E5, but often an E4 or even an E3) and his supervisor, the Fire Direction Officer (FDO), who is typically a second or first lieutenant. A battery has one FDO and several BCU operators to maintain a 24 hour capability in the field. When a fire mission is received at the battery, the BCU computes the firing data (e.g., deflection, elevation, and charge) for each gun in the battery and transmits this information to the guns.

At each gun, the section chief (usually an E6, but sometimes an E5) receives the information on the screen of his hand-held SCA. At the same time, the elevation and deflection appear on the two GDU's which are mounted on the gun within sight of the gunner and assistant gunner. The gunner and assistant gunner (E5's, E4's, or E3's) mechanically adjust the gun's deflection and elevation, respectively.

After the shot is fired down range, the FIST observes the location of the shell's impact and uses the DMD to transmit back to TACFIRE (or the BCU operator, if operating in the autonomous mode) information concerning adjustments for the next round, or end of mission.

METHOD

Subjects

Two field artillery battalions and one FA battery from a third battalion participated in the BCS test. One of the FA battalions included three batteries of 8 inch self-propelled howitzers (8 SP). The other FA battalion consisted of three batteries of 155mm self-propelled howitzers (155 SP). Attached to the 155 SP battalion as a fourth battery ("D" battery), was a battery of 105mm towed howitzers (105 T). In addition, maintenance soldiers from the division direct support (DS) maintenance battalion received maintenance training on BCS and provided DS maintenance during the test. Table 1 lists the number and types of personnel in these units who completed human factors questionnaires.

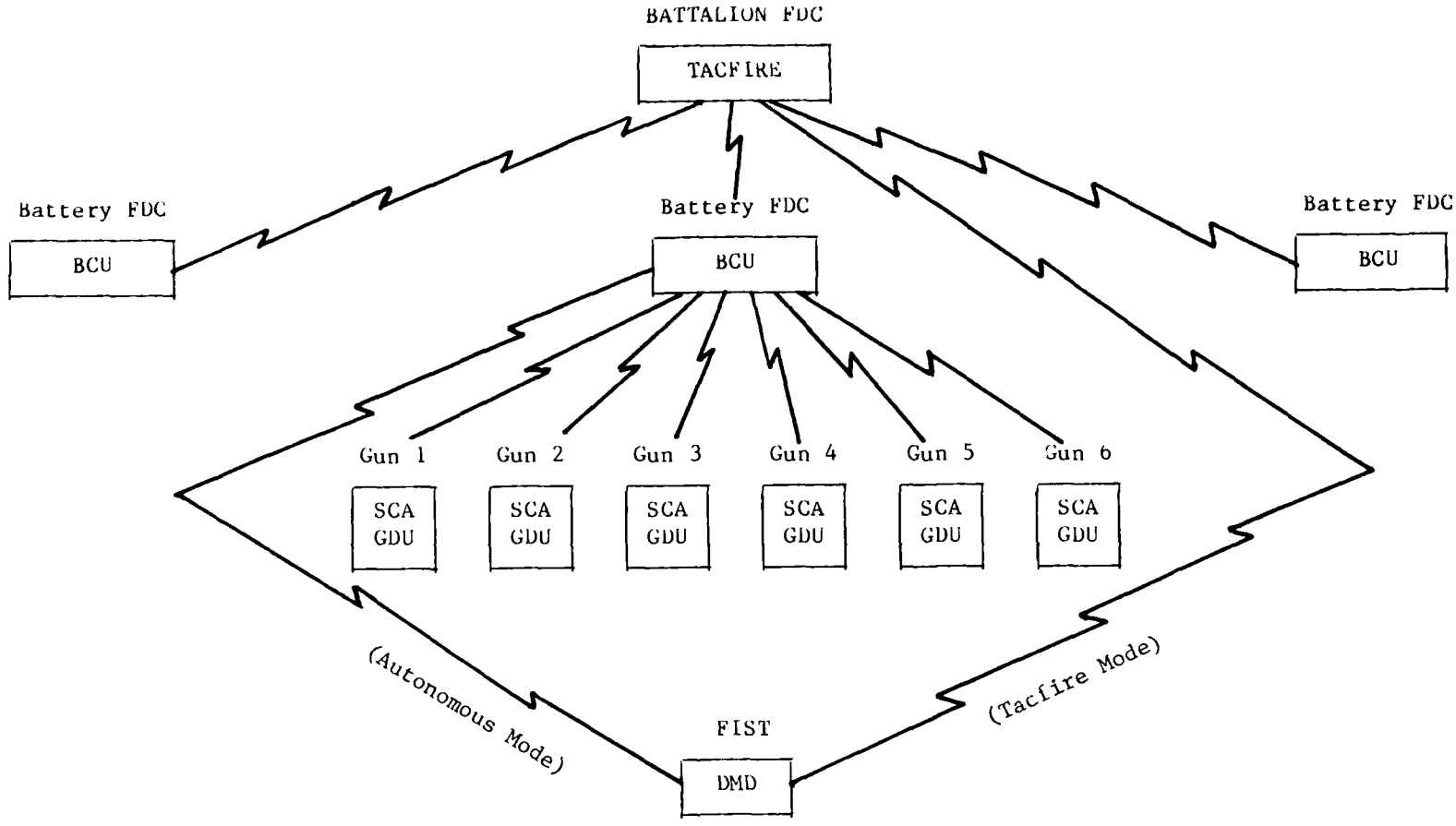


Figure 2. Configuration of the Battery Computer System within the Field Artillery Battalion

TABLE 1

Types and Numbers of Soldiers Who Completed Questionnaires for BCS Human Factors Evaluation

Duty Position	MOS	Ranks Represented in Duty Position	Number of Respondents by Unit Type					
			8SP	155SP	105T	Mnt Bn	OTEA	Ttl
BCU Users								
FDO	12A	1LT,2LT	3	3	1			7
BCU Operator	13E	E6,E5,E4,E3,E2	5	6	3			14
SCA Users								
Sec Chief	13B	E6,E5		13	4			17
GDU Users								
Gunner and Asst. Gunner	13B	E5,E4		28	12			30
BCS System Users								
BN CO	13A	LTC	1	1				2
BN XO	13A	MAJ	1	1				2
BN S3	13A	MAJ	1	1				2
Maintainers	34Y,27E	E6,E4,E3				6		6
OTEA Maintenance Data Controllers	286A,31V	CW2,E7					2	2

Questionnaires

Eight questionnaires were developed to assess the human factors implications of BCS. For the most part, the questionnaires consisted of five-point rating scales where, for example, ratings from the BCS soldiers in terms of how easy it was to perform various functions of the BCS were as follows: 5 - very easy, 4 - easy, 3 - borderline, 2 - difficult, and 1 - very difficult. Space was provided for recording respondents' explanations of their ratings. Typically, an individual would be asked to complete a questionnaire during his free time in the field. After completing it, one of the authors of this report would then review his responses with him and record on the questionnaire his explanations of adverse ratings given to various parts of the system. Table 2 lists the short title of the questionnaires, the people receiving them, and the general content areas of each one. The complete questionnaires used are included in Appendix B.

Procedure

Between November of 1981 and April of 1982, the 155 SP and 8 SP battalions and the 105 T company received classroom training and undertook three 5-day field exercises to test BCS. During the months of November through January FDO's and BCU operators from these units attended a two-week BCU operators course at Fort Sill, Oklahoma, while two maintenance personnel from OTEA, and six maintenance personnel from the division maintenance battalion attended a one-week BCS maintenance course at Fort Sill. During January 1982, instructors from Fort Sill provided a 12 hour training course at Fort Hood for section chiefs in the 8 SP battalion.

In early February 1982, Fort Sill instructors were again on hand at Fort Hood to assist in a 12-day collective training program where the 155 SP battery and the attached 105 T company set up in the motor pool area and as a unit practiced processing fire missions with BCS.

The actual field exercises to test BCS were conducted during late Februay and March of 1982. Each of the three field exercises were five days in length with five days between exercises. The simulated combat environment for each of the five-day exercises provided for one day of live fire and four days of dry fire, a number of day and night movements, and periodic simulations of NBC (Nuclear, Biological, Chemical) environments during which personnel in the field were required to wear full NBC protective clothing (MOPP IV).

During the field exercises, only the 155 SP battalion (reinforced with the 105 T company) took all their personnel and guns to the field. The 8 SP battalion took only the battalion FDC, the battery FDC's, their FIST, and their guns, but the GA's were not mounted on the guns and they did not fire live ammunition.

The human factors questionnaires (Appendix B) were administered during the last few days of the third exercise.

TABLE 2

List of Human Factors Evaluation Questionnaires

Short Title	Content Area	Designated Respondent
Operator	Operation, maintenance and Safety of BCU	BCU Opertors and FDO's
Section Chief	Operation, maintenance and Safety of SCA	Section Chiefs
Gunner	Operation of GDU	Gunners and Assistant Gunners
FDO	Logistics and Training Requirements of BCS	FDO's
Maintainer	Maintenance and Safety of BCS	Maintainers
ASL/PLL	Adequacy of Replacement Parts	Supply Personnel
Battery Commander	Logistics and Training Requirements of BCS	Battery Commanders
Battalion CO/S3	Logistics and Training Requirements of BCS	Battalion Commanders, Executive Officers and Operations Officers

RESULTS AND DISCUSSION

The results of the human factors evaluation of BCS will be presented and discussed with respect to the major areas of mission performance of BCS and the logistics and maintenance requirements of BCS. The questionnaire results are presented in Appendix A. These results show for each question the number of responses falling into each rating category. Associated comments given by the respondents are discussed in the text of the report.

Mission Performance

Mission performance evaluation of BCS is divided into six subareas: tactical operations, error handling, confidence in the system, appropriateness of displays and controls for day-night operations, NBC operations and safety.

Tactical Operations. In this area, concern focused on potential human factors problems associated with the BCS operations of system start-up, message transmission, fire mission processing, and system shut-down. Response frequencies to the individual questionnaire items are presented in Tables A-1 and A-2 for operation of the BCU and GDU, respectively.

With respect to system start-up, there were few reported problems with powering up the BCU, loading the initial programs and initialization (Table A-1, questions 1 through 9). The one operator who indicated that loading programs was "Difficult" commented that he did so because loading programs took too long when it was necessary to perform "hip-shots." By far, most of the negative ratings in system start-up dealt with problems encountered while attempting to establish communications with subscribers (TACFIRE, other BCU's, and FIST) and with the GDU's. Six operators and FDO's commented on the problem of maintaining serialization. In addition, three commented on the difficulties in using wire to link the BCU with the GDU's. There was also one comment that the PRC-68 radio link between the BCU and GDU's failed due to poor batteries.

With respect to message-transmission (questions 10 through 16 of Table A-1), the problems fell into two main categories. Four people commented again on the problems in maintaining serialization for digital traffic, and four people commented on problems with messages to the GDU's over wire. Some units used only one wire to the GDU's for both voice and digital messages. While this saved wire and avoided the problem of getting wires crossed during initial hook-ups, there was the added problem of the voice and digital traffic interfering with each other. One FDO also commented that when a message transmisison problem occurred, it was difficult to identify the source of the problem, i.e., the KG-31, BCS or the radios.

There were relatively few problems noted with the actual processing of various types of fire missions (Table A-1, questions 17 through 33). In fact, most of the operators and FDO's felt that when communications were good, the BCS made the processing of fire missions "Very Easy" or "Easy." Some minor problem areas were noted, however. An operator and FDO rated questions #18, "adjusting fire mission using grid coordinates," as "Difficult" under TACFIRE but not under the autonomous mode. This was most likely caused by increased transmission

difficulties resulting from serialization problems with TACFIRE. This may also be the basis of the "Difficult" rating one operator gave to question #20; "adjusting using a shift from a known point." On question #22, processing HB/MPI (high burst/mean point of impact) registrations, one FDO commented that it would be helpful if orienting data sent to both forward observers contained a vertical angle so that the observers would not have to manually orient their aiming circles. Several operators and FDO's noted difficulty with processing illumination missions (question #25). One FDO suggested that illumination missions were incorrectly explained in the user's guide and that illumination missions would be easier if the guns were entered in the SPTF field of the message format. In processing quick smoke missions (question #29), one FDO commented that BCS does not compute the intervals to fire between rounds but treats the rounds as one volley. This means the FDO has to use voice to inform the guns when to fire each shot AMC (at my command). When handing off fire missions (question #30), an operator noted that the message traffic concerning that mission still passed through his system, tying up his own communications. And finally, one FDO noted that when entering MVV information (question #32), extra time is needed because a fake mission must be computed for the charge.

No one reported any difficulties in shutting the system down (Table A-1, questions 34 and 35). Two additional questions (#36 and #37) were asked to cover potential problem areas. Three FDO's indicated that initialization required non-SOP data. Two FDO's commented that with BCS they now had to input each gun's azimuth from the aiming circle while the remaining FDO noted that BCS does not need the GFT (graphic firing tables). The FDO who indicated he had changed the sheaf of a fire mission said he did so during a dry fire mission just to see the different computations involved in computing a circular and linear sheaf.

The subjective ratings with respect to operating the GDU's (Table A-2) indicate that section chiefs firing the 105mm towed howitzers indicated fewer difficulties than the section chiefs on the 155mm self-propelled howitzers. All four of the section chiefs of the 105 T unit indicated that their mission response would be faster if the charge appeared on the SCA first. In firing the 105's, cutting the correct charge takes the longest time. While the section chiefs in the 155 SP indicated a higher level of difficulty than did the 105 T sections chiefs, they did not mention specific reasons. One section chief did note that Copperhead missions seemed to take longer under the new system.

Error Handling. Specific questions were asked of BCU operators and FDO's to assess potential human factor problems pertaining to the adequacy of BCU error messages. The response frequencies are presented in Table A-3.

Only four out of 14 operators indicated that error messages were "Borderline" or "Difficult" to understand while three out of seven FDO's indicated error messages were "Borderline" and one FDO indicated they were "Very Difficult." This latter FDO commented that there were no explanations for many of the error messages. Three of the other operators/FDO's commented that the error message was too general or the further explanation in the manual was not helpful. The most common example that was cited was that there is no explanation of a "Buffer 4" error in the manual.

Four operators and one FDO gave "correcting errors" a "Borderline" rating. One of these operators commented that when a new forward observer (FO) was assigned and the BCU did not receive an "acknowledgement" the operator could not figure out why. The FDO commented that after executing a mission from an FO, it is hard to change the mission if the FO wants to make a correction. Five operators and two FDO's indicated there were ways to get around some error messages without correcting them, however. Their comments were to the effect that with a "Buffer Full" message, the message disappears if one merely powers down and then up again; with a "PTM," you can just press the space bar and retransmit; and finally, if the operator gets an FM:FC from TACFIRE that is out of serialization and thus cannot be executed, the FM:FC can be deleted, the data entered into an FM:RFAF, and the fire mission then transmitted to the guns under this new format.

System Confidence. Because the howitzer section chief supervises the loading of the round in the tube and gives the final command to fire, his level of confidence in the new computerized system was assessed. The frequency of the section chiefs' responses is presented in Table A-4.

Six of 14 section chiefs indicated less than "High Confidence" in using the SCA. There were three types of negative comments about the SCA. The first type of comment (made by two section chiefs) concerned receiving unsafe data. One section chief felt nervous when BCS required one kind of charge in adjusting but another kind to fire the fire for effect (FFE) from the adjustment. The second type of comment indicated just more faith in voice commands. A related comment made by one section chief mentioned that mixing the SCA commands with voice was sometimes confusing. The third type of comment, made by five section chiefs,concerned issues of the unreliability of the system. Some chiefs were aware that one SCA had lost its data during a fire mission, presumably because of gun vibrations during firing. Four chiefs noted, however, that the largest source of unreliability was the batteries. SCA batteries seemed to be unpredictable and would die without reason. Section chiefs suggested that some guage to check the amount of battery life remaining would facilitate charging low batteries prior to important missions. One positive comment was obtained: a section chief said that since he had now used the SCA, he found artillery operations better than without it.

Displays and Controls. This section assessed the ease of viewing and operating the displays and controls during day and night operations. Table A-5 presents the response frequencies to the individual questionnaire items.

Viewing and operating the BCU was rated as "Easy" or "Very Easy" by most of the operators and FDO's. The one problem area uncovered was viewing the BCU visual display in daylight (questionnaire item #1). Comments accompanying the negative ratings for this item indicate problems when direct sunlight hits the display screen. This often occurred for units where the BCU was mounted in the M577A1 CP Carrier because there is a hatch above the BCU operator. This hatch is open on warm sunny days to allow for air ventialation. When the sun shines through the hatch onto the BCU screen operators had to use their hand to cast a shadow on the screen in order to read the plasma display. Several operators and FDO's suggested that a pull-out sun-shield attached to the BCU would help.

The one operator rating item eight as "Difficult" reported that the FDO's headset-side of the BCU was hard to see at night and that all BCS dials ought to be marked with luminous paint. One other operator mentioned that the "execute key" came loose with constant use and that applying pressure to the corners of the "execute key" caused it to break easily. The minor problems mentioned with respect to viewing and operating the PDU (questions 9 through 12) were again mostly due to sunlight reflection.

Observations on the SCA (questions 13 and 14) revealed two problems: reflections of sunlight off of the display during the day, and difficulty in reading the display keys at night. Other comments by section chiefs indicated areas in which they felt the SCA could be improved. For example, several section chiefs thought that execution of the mission would be faster if all of the Fire Mission data were presented at once on a larger SCA display rather than sequentially on a small display as is currently done. Several also commented that it would be helpful if the sound of the alarm was different for each of the three functions of "fire mission", "check fire" and "end of mission."

With respect to the GA (questions 15 and 16), it was relatively easy to see the display at night, but again some problems were reported with sunlight reflecting off of the display when the GA was mounted outside on the 105mm towed guns. Several of these gunners suggested the need for a small pull-out hood for screening out sunlight on the GA.

NBC Environment. This section assessed the extent to which the BCS components could be operated while wearing NBC protective clothing. The response frequencies to the individual questionnaire items are presented in Table A-6.

Generally, the BCU operators and FDO's had no problem viewing the display and indicators of the BCU while wearing NBC clothing. One operator who indicated only "Borderline" for viewing the BCU visual display and indicators commented that the lower portion of the screen was harder to see than the upper portion, and one operator had to bend his head down a little to avoid a glare effect in the NBC mask. Four of the operators and only one of the FDO's indicated that viewing the keyboard was less than "Easy." One BCU operator who indicated "Borderline" commented that the NBC suit became so uncomfortably hot that everything was harder to do.

Five operators and four FDO's indicated "Borderline" or "Difficult" in operating the BCU keyboard, while only three people indicated problems with operating the BCU switches. The comments indicated that use of the gloves generally slowed an operator down, especially if he was a good typist (i.e., not a one-finger operator). Comments also indicated that the operator needed to be more careful when operating the keyboard with gloves on. One operator used a pen or pencil to press the keys while wearing NBC protective gloves.

Section chiefs of the 155 SP unit gave lower ratings than did section chiefs of the 105 T while using the SCA with NBC protective clothing. This was most likely due to the fact that the personnel had to operate in the enclosed hull of the 155 SP guns where it was typically much hotter than outside where 105 T company personnel operated. No written comments were provided by the section chiefs in this area.

None of the gunners or assistant gunners operating the 105mm towed guns indicated problems while seven of the 26 gunners/assistant gunners who operated during an NBC environment on the 155mm SP guns indicated some problems. As with the SCA's the difficulties for the 155mm SP gunners/assistant gunners is likely due to the fact that they operated in an enclosed space which became rather warm and uncomfortable when wearing NBC clothing.

Safety. The final area of concern in assessing the mission performance requirements of BCS is safety. Table A-7 presents the response frequencies for the pertinent questionnaire items on this topic. The chief complaint was the extreme noise level. While no one reported any actual hearing problems, most of the FDO's and about a third of the operators complained about the noise in the fire direction center (FDC). There were three types of comments concerning the noise which are related to the source of noise. First, most of the reported noise problems arise from the BCU alarm system. Comments indicated that it was too high pitched and that it stayed on too long. The alarm will remain on, for example, if BCU receives a message from TACFIRE but is in the process of computing a mission or polling the guns, and will remain on until that process is complete. The second major source of noise is the transmission of digital traffic. To insure digital traffic transmission, FDO's and BCS operators will increase their radio volume. If they then forget to turn the volume back down after receiving the digital traffic and subsequently receive voice traffic, when using the headphones, the volume is rather unpleasant. The third source of noise is just the number of FDC components operating constantly and, oftentimes, simultaneously. For example, there are usually two radios operating with both voice and digital traffic, a power generator parked next to the FDC, and the BCU alarm system. The evaluators' initial impression of this environment is amazement that people can think and work in such a noisy, confined space. While the noise level is only partially due to the BCS components, these components serve to increase the already high level of noise in this area.

Two other areas of safety in the BCU are heat and cuts. Comments related to heat indicated that no actual burns were incurred. It was mainly the discomfort of working with heat generating equipment with little ventilation available. One operator noted that the BCS "locked-up" once due to overheating. Comments related to cuts indicated that the lock-nuts on the KG-31 and PDU could cut or pinch one while loosening or tightening them. Two operators also noted that the lock bar below the BCU keyboard protrudes and that it is easy to bump your head on it when crawling under the keyboard to enter the hatchway into the vehicle driver's compartment.

The section chiefs' major safety concern on the GDU's also was loudness of the alarm system; however, it is interesting to note that one section chief commented that the alarm was not loud enough to always wake-up a sleeping person.

Logistics and Maintenance

Logistics and maintenance evaluation of BCS has been divided into four subareas: built in test equipment, tools and manuals, repair and replacement parts, and overall logistical concept.

Built-in Test Equipment (BITE). As can be seen in Table A-8, all of the section chiefs, operators, and FDO's indicated that the self-diagnostic tests were "easy" or "very easy" to perform. The only comment made was by an FDO who indicated that operators and FDO's should be told in training that sometimes a module will pass a self-diagnostic test even though a BIT lamp has come on. Apparently a BIT lamp will come on if an internal test module test is not completed in a given amount of time, even though there may be nothing wrong with the module. Most of the maintainers were also satisfied with the self-diagnostic tests, although one maintainer gave a "very inadequate" rating here. This maintainer's comments indicated that he did not feel that BCU operators could use the test adequately. The BCU operator comments, however, indicate that they can use the test adequately.

Tools and Manuals. Operators and maintenance personnel were asked to assess the adequacy and ease of use of tools and manuals. Response frequencies for questionnaire items pertaining to the adequacy, ease of use and availability of tools for BCS are presented in Table A-9 and A-10. It can be seen from Table A-9 that most BCU operators and FDO's did not know whether or not the tools they were issued for BCS were adequate. Most of the comments that accompanied these responses indicated that these individuals were not aware that the tool set issued for repairing the battery display unit (BDU) was to be used in repairing the whole BCS. This was also true of those individuals who gave inadequate ratings to the adequacy, ease of use, and availability of the tools. Several of these soldiers indicated that all that was really needed was a small screwdriver. Consequently, since screwdrivers are part of the tool kit issued with the BDU, it is reasonable to conclude that operators and FDO's would feel that the BDU tool kit is adequate for maintaining the BCS. Generally, maintenance personnel were satisfied with the tools they were issued for maintaining BCS (the tool kit issued to maintainers for repairing TACFIRE is used for repairing BCS).

Table A-10 shows mostly adequate ratings for type of tools, ease of use, and availability. The maintainer who gave a "Borderline" rating to the type of tools commented that there were really more tools available than he needed. The maintainer who was part of the OTEA test team and gave an "Inadequate" rating to the availability of tools commented that BCU operators in the field often did not have a screwdriver to open the cover on the BCU. As a result they frequently had to use a pocket knife instead. This latter would lead one to infer that BCS is easy to repair.

Table A-11 presents the response frequencies of FDO's, battery commanders, and selected individuals from the battalion command group, concerning the need for test and diagnostic equipment in the battery or battalion. Four of the six FDO's surveyed said that such equipment was needed. Their comments indicated that they felt that they had to wait too long for direct support maintenance

and would like to be able to do more troubleshooting on their own, e.g., testing cables and connectors. Three of the four battery commanders also indicated that they would like to have test and diagnostic equipment at battery level. Their comments revealed a concern with being able to better diagnose communications problems, and also being able to check out the section chief assembly by means other than just relying upon the self-diagnostic tests. Finally, two executive officers and one battalion commander also indicated a need for test and diagnostic equipment at battery or battalion level. The only specific comments made here indicated that there was a need to be able to test the batteries in the GDU.

Table A-12 shows the response frequencies for BCU operators and FDO's concerning satisfaction with the technical manuals. It can be seen that, generally speaking, about half of these individuals found both the Operators and Organizational Maintenance Manual and the User's Guide to be adequate in the various categories listed. Additionally, the majority of operators found the Operator's and Organizational Maintenance Manual to be easy to use for troubleshooting the BCS. Interestingly, about 25 percent of the operators never used this latter manual, while no one said that they never used the User's Guide. Those individuals who rated the manuals as "Borderline" or worse mentioned several problems. The most common complaint, mentioned by five of the operators, was that there were no indexes to the manuals and thus it was difficult to look up specific information in them. One operator tried to ameliorate the situation by putting tabs on the manuals to designate certain fire mission formats, error messages, and diagnostic tests. An additional problem which was mentioned by the operators and FDO's was that the manuals did not contain all of the information that was needed for operating the BCS. For example, one operator indicated that he could find no definition of "VTX" and "NVA" in the manuals. One of the FDO's supported this complaint by indicating that there were several things, such as a "buffer 4" error message for which he could find no explanation. Other problems included complaints about incomplete cabling diagrams and a lack of information on what to do in the event that one's serialization count becomes inaccurate. Finally, complaints with using the Operator's and Organizational Maintenance Manual focused on the desire for more information on how to troubleshoot communications problems.

With regard to the Operator's and Organizational Maintenance Manual for the gun display unit, Table A-13 shows that most section chiefs rated it as "Adequate" or "Very Adequate." Four of the 14 section chiefs who were questioned, however, said that they never used it.

Finally, the satisfaction of the maintainers with the Operator's and Organizational Maintenance Manual and with the Direct Support Maintenance Manual can be seen in Table A-14. Of the direct support maintainers, two indicated that they never used the manuals while the other two generally gave "Adequate" and "Very Adequate" ratings to various aspects of the manuals. Comments on the "Borderline" and "Inadequate" ratings regarding completeness of the Direct Support Maintenance Manual derived from the complaint that this manual did not contain enough information for maintaining the gun display unit. About half of the ratings given to the manuals by the two maintainers

who were part of the OTEA test team were "Borderline" or worse. The individual comments here revealed that these two individuals felt that the manuals should contain more theoretical explanations of the BCS operations. Finally, ratings of the adequacy of the manuals in terms of facilitating troubleshooting were either "Adequate" or "Borderline." The "Borderline" ratings were based on the preceding complaint that the manuals should contain more "theory of circuitry" so that a maintainer could really troubleshoot the system rather than just identify a bad card and replace it.

Repair and Replacement Parts. Ratings on the ease or difficulty in performing maintenance procedures are presented in Tables A-15 through A-17. Perusal of these tables reveals that there were relatively few complaints about maintenance procedures per se. Of the BCU operators and FDO's who performed the procedures listed in Table A-15, almost all indicated that the procedures wer "Very Easy" or "Easy" to perform. Similarly, most of the section chiefs indicated that performing maintenance procedures and assembling the GDU was "Very Easy" or "Easy" (Table A-16), although three section chiefs gave "Borderline" ratings to assembling the GDU and one section chief gave a "Very Difficult" rating to this procedure. Comments by two of these section chiefs indicated that knowing how to wire the case assembly to the gun assemblies was the major problem here. The major problem which the maintainers encountered involved the replacement of electrical cables. This problem received one "Borderline" and two "Very Difficult" ratings (Table A-17, question #11). Individual comments from the maintainers indicated that the problem revolved around the fact that there were numerous clamps which held all of the electrical cables together in one bundle behind the BCS and associated equipment in the M577A1 vehicle which housed the BCU. In order to replace a given cable, a maintainer had to reach behind the equipment (a rather awkward procedure) and cut each of these clamps in order to free the faulty cable from the other cables. This sometimes resulted in scraped knuckles and bruised hands. This, incidently, was the only safety hazard mentioned by any of the maintainers (Table A-18).

Table A-19 presents ratings by BCU operators, FDO's, maintenance personnel, battery commanders, and personnel of the battalion command group concerning the availability of replacement parts for BCS. The question concerning the adequacy of the availability of replacement parts received the worst ratings among the questions in the maintenance area. Of the 40 individuals who responded to this question, almost half (19) gave ratings of "Borderline" or worse. Only 12 individuals gave ratings of "Adequate" or better. A comment made by one BCU operator and one FDO was that a PLL (prescribed load list) containing boards at battery level would be useful since the operator is trained to diagnose faulty boards and replace them himself. Time is wasted when waiting to receive a board from the battalion PLL. This point was supported by one operator who noted that it once took eight hours to receive a replacement A10/12 commo board. Also, one of the FDO's reported having to wait three hours once for a control processor board. Additional items which two FDO's suggested for inclusion in a battery PLL were light bulb replacements for indicator lamps.

The maintainers, while not suggesting a battery PLL, had several suggestions for improving the battalion PLL. For example, two of the maintainers commented that the battalion PLL should contain GDU parts, such as

a section chief assembly, a case assembly, and electrical cables. One of the maintainers also noted that during the test there was actually no PLL, but rather all parts were kept in ASL (authorized stockage list), thus causing the direct support maintenance personnel to sometimes get involved in problems that should have been handled at an organizational maintenance level. The comments of the ASL parts personnel were similar to those of the maintainers, indicating a need for more GDU's in the ASL, which contained only one GDU.

Among battery commanders there was one "Borderline" rating and one "Inadequate" rating in this area. The commander giving the "Borderline" rating, however, commented that he actually had not had time to evaluate PLL needs. The commander giving the "Inadequate" rating supported comments by operators and FDO's that there should be some sort of PLL at battery level. Comments among the battalion command group personnel centered on the need for GDU parts in the PLL. Three individuals (all from the live firing battalion) commented on this problem. Also, one individual suggested that more boards be added to the battalion PLL.

Overall Logistical Concept. The adequacy of the overall logistical concept was assessed by eliciting questionnaire responses from FDO's, Battery Commanders, Battalion Commanders, XO's and S3's. These responses are presented in Table A-20. In addition, an interview of the maintenance battalion commander was conducted three weeks after the final tactical exercise.

Three of six battalion CO's, XO's and S3's rated the overall logistical concept as "Borderline" or "Inadequate." The comment associated with the "Inadequate" rating stated that time for replacement averaged 7-10 hours. A "Borderline" rating came from one individual who added that the present centralized system would not work in war: the response time was poor and the DS contact team personnel served not as repairers but rather as parts runners. Four of six of these officers answered "Yes" to the need for battery or battalion level maintenance personnel. These people commented on the problem of having to go outside the battalion for assistance in software problems, replacement parts, and installation. Three of the six battalion officers said "Yes" to the need for a separate BCS maintenance MOS. The comments in this section indicated that the 34Y's were overpowered with TACFIRE, and a system of the magnitude of BCS should not come in second for repair; both a 34Y and a BCS maintenance specialist should be assigned to the battalion. One comment accompanying a "No" response stated that a separate MOS was not necessary if the maintainer was knowledgeable in BCS operation.

Three battery commanders rated the overall logistical support concept as "Adequate" while two commanders rated it as "Borderline" or "Inadequate." The commander giving the "Inadequate" rating stated that the response time was too slow and that if the logistical support thrust is to replace subunits then this effort would be better supported by increasing the battalion PLL. Only two commanders indicated a need for battalion level maintenance personnel. Their comments indicated that DS was too far away and that their operators only had the minimum level of maintenance training. One "No" commander commented that his unit BCS did not need any maintenance outside of one card replacement. One battery commander indicated a need for a separate BCS

maintenance MOS because he thought the DS maintenance personnel were inadequate in their ability to diagnose and rectify BCS problems; all they did was replace entire BCU's. Five of the seven FDO's rated the overall logistical concept as "Adequate." The one FDO giving a "Very Inadequate" rating commented that the response time was slow and that the DS maintenance personnel need to know how to operate BCS. Three FDO's cited a need for battalion-level maintenance personnel. These FDO's objected to meeting all unsolved problems with replacement of units. Another one reported that when a central processing board went out he had to wait for battalion PLL. He felt that these could be carried at battery level. One FDO suggested sending a soldier with a 31V MOS from battalion level communications to a two-week BCS maintenance class. The one FDO who indicated a need for a separate BCS maintenance MOS commented that TACFIRE and BCS are not operated or repaired in the same way.

Two of the maintainers rated the overall logistical concept as "Inadequate." The major comments indicated that the DS personnel were not adequately utilized. They were used as parts carriers instead of maintainers. DS personnel were doing things the BCU operator could have done, given a supplemented PLL. DS personnel never did any hands-on parts replacement, e.g., power supply or front panel assembly. Sixty percent of DS call-outs could have been performed by a well trained BCU operator. All of the maintainers agreed that there was no need for a separate BCS MOS; however, almost all felt that they needed more personnel. The maintainers commented that there were only four DS maintainers during the test and this was not enough for 24 hour contact-team service to the units without accumulating a large backlog of TACFIRE maintenance.

Finally, an informal interview with the commander of the division level maintenance battalion that provided the direct support maintenance to BCS during the field test revealed a very pressing concern on his part. The problem was that the maintenance battalion had not been authorized any additional personnel in order to maintain the BCS, but rather the eight personnel which the battalion was authorized for TACFIRE were supposed to also support BCS. Support of BCS was only accomplished during the field test, however, by delaying the repair of TACFIRE components. The battalion maintenance commander expressed serious reservations about the Army's ability to maintain battlefield automated systems as they become introduced into the inventory in increasing numbers unless serious consideration is given to supplying maintenance units with additional trained personnel for maintaining them.

SUMMARY AND CONCLUSIONS

Several major conclusions can be drawn from the previous results. They are most appropriately discussed under the general headings of Mission Performance, and Logistics and Maintenance.

Mission Performance

Tactical Operations - One of the most common problems which was encountered in operating the BCS involved the establishment of communications between the BCU and other systems such as TACFIRE, other BCU's, FIST's and even the GDU's. Operators of the BCU's appear to need more training in dealing with the various types of communication problems that are likely to occur with BCS, such as the incorrect connection of wires going from the BCU to the gun assemblies and the failure to maintain the correct serialization of the BCU when it is interoperating with TACFIRE. It was not uncommon for a BCU to get out of synchronization with TACFIRE during the field exercises of the test, thus causing a delay in the processing of fire missions. The BCU operators learned how to get the system back in synchronization during the course of the test, but the process involved is somewhat tedious and requires a bit of experience in order to avoid losing much time when fire missions are being sent out by TACFIRE at a fairly rapid rate. Thus, additional operator training on how to deal with this problem would likely provide benefits in terms of reduction of down time on the battlefield that would far outweigh the additional costs in added training time.

Error Handling - While there were no major problems reported with handling errors that occurred while operating the BCU, it was discovered that one particular error message that sometimes appeared on the BCU display was not explained in the operator's manual. This error message was "Buffer 4," and should be included in future revisions of the operator's manual.

Displays and Controls - The major problem that was reported in this area concerned the difficulty of reading information off of the BCS displays when they were exposed to direct sunlight. This was a problem for the BCU display, for the SCA display, as well as for the GDU display. It should be noted that this problem is not unique to BCS but is a problem in most systems in which displays must be used in bright sunlight. The light reflects off of the surface of the display and diminishes the contrast characteristics of the display to the extent that the information being presented in the display cannot be seen or can only be seen with difficulty. The most readily available and immediate solution to this problem, and one which several of the questionnaire respondents mentioned themselves, is to mount small retractable heads on the sides and/or top of the displays so that they can be extended out when needed to shield the display from direct sunlight.

Operating BCS in NBC Protective Clothing - Generally speaking, the users of the BCS experienced no major problems in operating the system while wearing NBC protective clothing. The primary effect which operators reported was that it slowed them down. For example, they indicated that they could not enter information through the BCU keyboard as fast with NBC gloves as without them. Also, they felt that the gloves caused them to make more errors than they

normally would because the large size of the glove fingers sometimes resulted in inadvertently pressing two keys simultaneously. This latter problem was solved by using a pencil or pen to press the keys. Of course this solution precludes using the touch typing method of entering information through the keyboard and contributes to slowing down BCU operations when wearing NBC protective gear.

Safety - No major safety problems were reported with the BCS. However, there were numerous complaints voiced about noise levels when the question of safety was broached. For example, there was a fair amount of personal annoyance expressed toward the auditory alarm which sounded in the BCU whenever a fire mission from TACFIRE was received. The complaints were that the alarm was too high pitched and stayed on too long for personal comfort. It should be noted, however, that this is not necessarily a bad aspect of an alarm that is installed to get an operator's attention when an important message has arrived. The other complaint about noise centered on the problem of turning up the volume on a radio set to insure the transmission of digital traffic, and then later putting on earphones to receive a voice transmission and forgetting that the volume is turned up. The resulting loud transmission through the earphones was very annoying to some individuals. The casual observations of the authors of this report, however, indicate that operators rapidly learn to attend to the volume setting on their radios while they are wearing earphones and thus this is only a problem to inexperienced operators for a short time.

Logistics and Maintenance

Built-in Test Equipment - Most users of BCS found the built-in test equipment easy to use.

Tools and Manuals - BCS operators and maintainers were basically satisfied with the tools that they were issued for maintaining and repairing the system. Some dissatisfaction, however, was expressed toward the technical manuals with the major complaint being that there were no indices in the back of the manuals that could be used to rapidly locate needed information. Future issues of both the Operators and Organizational Maintenance Manual and the User's Guide should include comprehensive and functional indices. Also, the Direct Support Maintenance Manual should be reviewed to ensure that it contains enough information for maintaining the gun display unit.

Repair and Replacement Parts - The most troublesome repair procedure involved the replacement of electrical cables which were bound together in bundles behind the BCS when it was mounted in an armored command vehicle. Access to the cables was extremely limited and tying them into bundles merely caused problems in trying to separate out a given cable from the bundle when it needed to be replaced. Consideration should be given to not tying these cables together during production of the system since maintenance personnel never retie them once they have separated them during repair operations.

An additional problem which emerged in this area concerned the amount of time required to replace computer boards in the BCU. BCU's which were down

for several hours during the test could frequently have been operational again within a few minutes after going down if there had been a battery level PLL which contained items that were the most common causes of failure of the BCU, such as commo boards.

Overall Logistical Concept - The most important consideration which emerged in this area concerned the need for additional maintenance personnel to repair and maintain the BCS. Comments from the artillery battalion personnel as well as from the maintenance battalion commanders indicate that the current level of manning in the direct support maintenance battalion is not adequate to satisfactorily meet the maintenance requirements of BCS.

General Conclusions

It is obvious from the preceding remarks that there are numerous man-machine interface problems with BCS that, if corrected, would yield a much more effective combat system. However, it should be noted that the system as a whole remained operational during the test in spite of these problems. The troops who used it were at least able to handle most of these problems to the point of being able to operate the system at a level of effectiveness that was useful, although certainly not close to optimal.

APPENDIX A

Questionnaire Results

TABLE A-1

BCU Operator and FDO Ratings of the Ease or Difficulty of Operating the BCU

System Start-up	Operators (N=14)						FDOs (N=6)					
How easy or difficult is it to perform each of the following procedures:	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Powering Up.	7	6	1	0	0	0	6	0	0	0	0	0
2. Loading program.	7	5	1	1	0	0	6	0	0	0	0	0
3. Initialization/ creation of a data base.	5	8	0	0	0	1	1	5	0	0	0	0
4. Establish communication with subscribers												
a. By radio	0	9	4	1	0	0	1	1	4	0	0	0
b. By Wire	3	7	2	0	0	2	1	2	2	0	0	1
5. Establish communication with GDU's												
a. By Radio	2	4	0	1	1	6	0	0	0	0	1	5
b. By Wire	4	4	4	1	0	1	1	2	2	1	0	0
6. BCU data base update for occupation of a new position	3	10	0	0	0	1	3	3	0	0	0	0
7. BCU data base (files) update during operation	5	9	0	0	0	0	4	2	0	0	0	0
8. Recording the data base	6	8	0	0	0	0	5	1	0	0	0	0
9. Restarting the system after a power failure	7	7	0	0	0	0	5	1	0	0	0	0

TABLE A-1 (con't)

Message transmissions	Operators (N=14)						FDO's (N=7)					
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
10. Communicating by voice with GDU	5	4	5	0	0	0	1	1	2	1	1	1
11. Communicating digitally with GDU.	4	5	5	0	0	0	1	5	0	1	0	0
12. Sending messages.	6	7	1	0	0	0	3	3	1	0	0	0
13. Receiving messages.	4	8	2	0	0	0	3	2	2	0	0	0
14. Understanding message formats.	4	9	1	0	0	0	1	6	0	0	0	0
15. Authenticating messages manually.	2	6	1	0	0	5	1	0	1	1	1	3
16. Serialization of messages using the KG-31.	3	6	3	1	1	0	0	4	3	0	0	0
Processing fire missions												
17. Aborting a gun order computation.	4	6	1	0	0	2	2	5	0	0	0	0
18. Processing adjust fire missions using grid coordinates												
a. With TACFIRE	3	9	1	1	0	0	5	1	1	0	0	0
b. Autonomous.	6	7	0	0	0	1	4	3	0	0	0	0
19. Processing adjust fire missions using polar plots												
a. With TACFIRE.	3	7	1	1	0	2	5	2	0	0	0	0
b. Autonomous	5	7	0	0	0	2	4	3	0	0	0	0
20. Processing adjust fire missions using shift from a known point.												
a. With TACFIRE.	2	6	0	1	0	5	5	2	0	0	0	0
b. Autonomous.	3	6	0	0	0	5	4	3	0	0	0	0

TABLE A-1 (con't)

	Operators (N=14)						FDO's (N=7)					
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
21. Processing precision registration fire mission (autonomous only).	2	9	2	0	0	1	3	3	0	1	0	0
22. Processing HB/MPI registration (autonomous only).	0	7	2	0	0	5	0	4	0	2	0	1
23. Processing FFE fire missions.												
a. With TACFIRE.	4	8	1	0	0	0	6	1	0	0	0	0
b. Autonomous.	7	7	0	0	0	0	4	2	0	0	0	0
24. Processing FPF missions.												
a. With TACFIRE	3	7	1	1	0	2	2	4	0	1	0	0
b. Autonomous.	5	7	1	0	0	1	2	4	0	0	0	1
25. Processing Illumination missions.												
a. With TACFIRE	0	2	0	2	0	9	1	2	1	0	0	3
b. Autonomous.	0	3	0	0	0	9	2	1	1	0	0	3
26. Processing Laser Missions.												
a. With TACFIRE	0	0	0	0	0	13	0	3	0	0	0	4
b. Autonomous.	1	1	0	0	0	11	2	2	0	0	0	3
27. Processing Copperhead missions.												
a. With TACFIRE	0	1	2	0	0	10	0	3	0	0	0	4
b. Autonomous.	2	1	1	0	0	9	2	2	0	0	0	3
28. Processing simultaneous fire missions.												
a. With TACFIRE	4	7	1	1	0	0	3	3	0	1	0	0
b. Autonomous.	5	6	1	0	0	1	3	4	0	0	0	0

TABLE A-1 (con't)

	Operators (N=14)						FDO's (N=7)					
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
29. Processing Quick Smoke (screening) missions.												
a. With TACFIRE.	0	3	0	0	0	10	0	0	1	0	0	6
b. Autonomous	0	2	1	0	0	10	0	1	1	0	0	5
30. Handing off fire missions to another BCU	0	5	3	1	0	4	2	1	3	0	0	1
31. Reacting to checkfire.	2	8	0	0	0	3	4	2	0	0	0	1
32. Performing special computations (replot, MVV).	0	3	2	0	0	8	1	3	2	0	0	1
33. Processing fire missions from a previously stored fire plan.	0	10	1	0	0	2	0	3	0	1	0	2
System Shut Down												
34. Powering down.	10	4	0	0	0	0	6	1	0	0	0	0
35. Displacement (March ordering to a new position.	7	7	0	0	0	0	6	1	0	0	0	0
Other												
36. Was the data that you entered into the system during initialization ever different from that required by your unit SOP?	Yes 0		No 13				Yes 3		No 3			
37. Did you ever change the sheaf of a fire mission?	Yes 0		No 14				Yes 1		No 6			

Note: Total number of responses to each questionnaire item may differ because some respondents did not perform the task or omitted an answer.

TABLE A-2

Section Chief's Ratings of Operating the GDU

How easy or difficult is it to perform each of the following procedures?	105T (N=4)					155SP (N=13)				
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Very Easy	Easy	Borderline	Difficult	Very Difficult
1. Turn on/Turn off GDU	4	0	0	0	0	10	2	1	0	0
2. Processing area fire missions	4	0	0	0	0	5	5	3	0	0
3. Receiving updated fire data	4	0	0	0	0	8	2	2	1	0
4. Processing final protective fire missions	4	0	0	0	0	6	5	2	0	0
5. Processing other fire mission. (e.g., Copperhead, ICM)	4	0	0	0	0	7	2	3	0	0
6. Receiving special instructions, such as cease loading and check fire	2	1	0	0	0	9	2	1	0	0

NOTE: Total number of responses to each questionnaire item may differ because some respondents did not perform the task or omitted their answer.

TABLE A-3

BCU Operator and FDO Ratings of the Ease or Difficulty of Using Error Messages and Recovery Procedures

How easy or difficult is it to perform the following procedures:

1. Understanding error and warning messages

	Operators (N=14)	FDO's (N=7)
Very Easy	2	1
Easy	8	2
Borderline	3	3
Difficult	1	0
Very Difficult	0	1

2. Correcting Errors

Very Easy	1	0
Easy	9	6
Borderline	4	1
Difficult	0	0
Very Difficult	0	0

3. Are there ways to get around error messages without correcting them?

Yes	5	2
No	9	4

TABLE A-4

Section Chiefs' Ratings of Confidence in BCS System

Questionnaire Item:

How much confidence do you have in the accuracy of the fire commands which you receive through the section chief assembly without voice verification?

4	Total Confidence
4	High Confidence
4	Some Confidence
2	Little Confidence
0	No Confidence

Note: 14 of 17 Section Chiefs completed this item.

TABLE A-5

BCU Operator and FDO Ratings of the Ease or Difficulty of Viewing Displays and Operating Controls

Viewing and Operating How easy or difficult is it to perform each of the following procedures:	BCU Operators (N=14) Very Easy / Easy / Borderline / Difficult / Very Difficult	FDO's (N=7) Very Easy / Easy / Borderline / Difficult / Very Difficult
BCU		
1. Viewing the BCU visual display in daylight.	5 4 1 2 2	1 3 3 0 0
2. Viewing BCU indicators in daylight.	5 7 2 0 0	2 5 0 0 0
3. Operating the BCU Keyboard in daylight.	10 4 0 0 0	6 1 0 0 0
4. Operating BCU switches and controls in daylight.	10 4 0 0 0	5 2 0 0 0
5. Viewing the BCU visual display at night.	11 3 0 0 0	6 1 0 0 0
6. Viewing BCU indicators at night.	10 4 0 0 0	6 1 0 0 0
7. Operating the BCU keyboard at night.	10 4 0 0 0	4 3 0 0 0
8. Operating BCU switches and controls at night.	9 4 0 1 0	4 3 0 0 0
PDU		
9. Operating controls and switches of PDU during daylight.	12 1 1 0 0	6 1 0 0 0
10. Operating controls and switches of PDU at night.	10 2 1 0 0	5 2 0 0 0
11. Viewing indicators on PDU during daylight.	9 4 1 0 0	5 2 0 0 0
12. Viewing indicators on PDU at night.	7 4 0 0 0	6 1 0 0 0

TABLE A-5 (con't)

How easy or difficult is it to perform each of the following procedures:	105T Section Chiefs (N=14) Very Easy / Easy / Borderline / Difficult / Very Difficult	155SP Section Chiefs (N=13) Very Easy / Easy / Borderline / Difficult / Very Difficult
SCA		
13. Viewing displays and controls during daylight.	1 0 1 0 2	7 3 3 0 0
14. Viewing displays and controls at night.	3 0 0 0 0	9 1 2 1 0
	105T Gunners/AG's (N=12)	155SP Gunners/AG's (N=28)
GA		
15. Reading gun assembly display during daylight.	3 3 6 0 0	17 11 0 0 0
16. Reading gun assembly display during nighttime.	11 1 0 0 0	19 8 1 0 0

TABLE A-6

Subjective Ratings of Operating BCS in an NBC Environment

Frequency of Responses

Questionnaire Items	Operators (N=13)	FDO's (N=7)
How easy or difficult is it to perform the following operations while wearing an NBC protective mask and protective gloves?	Very Easy / Easy / Borderline / Difficult / Very Difficult / Did Not Perform	Very Easy / Easy / Borderline / Difficult / Very Difficult / Did Not Perform
BCU		
1. Viewing the BCU visual display.	1 7 3 0 0 2	2 3 0 0 0 2
2. Viewing the BCU indicators.	1 8 2 0 0 2	2 3 0 0 0 2
3. Viewing the BCU keyboard	1 6 3 1 0 2	2 2 1 0 0 2
4. Operating the BCU keyboard	1 5 4 1 0 2	1 0 4 0 0 2
5. Operating the BCU switches and controls.	1 8 2 0 0 2	3 1 1 0 0 2
Section Chief Assembly	**105T Section Chiefs (N=11)**	**155SP Section Chiefs (N=13)**
6. Viewing displays and controls while wearing NBC protective mask.	2 1 1 0 0 0	6 3 2 0 2 0
7. Operating controls while wearing NBC protective gloves.	3 1 0 0 0 0	2 5 4 1 0 1
Gun Assembly	**105T Gunners (N=11)**	**155SP Gunners (N=28)**
8. Reading gun assembly display while wearing NBC protective mask.	3 7 0 0 0 1	9 10 1 2 4 2

TABLE A-7

Safety

Indicate if you experienced any of the following safety hazards while operating the BCS or GDU	BCS		GDU
	Operators (N=14)	FDO's (N=7)	Section Chiefs (N=17)
Electrical shock	0	0	1
Extreme Heat	3	2	0
Cuts from the GDU	2	0	2
Extreme brightness	0	0	0
Extreme loudness	5	5	3

Note: Some questionnaire item response frequencies do not sum to the total number of respondents available due to ommitted responses.

TABLE A-8

Key Personnel and Operator Ratings of
Self Diagnostic Procedures

1. How easy or difficult is it to perform the self-diagnostic tests?

	Section Chiefs (N=17)	BCU Operators (N=14)	FDO's (N=7)
Very Easy	14	9	4
Easy	3	5	3
Borderline	0	0	0
Difficult	0	0	0
Very Difficult	0	0	0

1. How adequate or inadequate were the operator-assisted diagnostic tests?

	Direct Support Maintainers (N=4)	OTEA Maintainers (N=2)
Very Adequate	1	0
Adequate	1	2
Borderline	1	0
Inadequate	0	0
Very Inadequate	1	0

TABLE A-9

BCU Operator and FDO Ratings of the
Adequacy and Ease of Use of Tools

1. Type of tools and test equipment issued for performing organizational maintenance.

	BCU Operators (N=13)	FDO's (N=6)
Very Adequate	0	0
Adequate	2	1
Borderline	2	0
Inadequate	0	2
Very Inadequate	0	1
Don't Know	9	2

2. Ease in using the prescribed tools and test equipment.

	BCU Operators (N=13)	FDO's (N=6)
Very Adequate	0	0
Adequate	3	1
Borderline	0	0
Inadequate	0	0
Very Inadequate	0	1
Don't Know	10	4

3. Availability of the prescribed tools and test equipment.

	BCU Operators (N=13)	FDO's (N=6)
Very Adequate	0	0
Adequate	2	1
Borderline	1	0
Inadequate	0	0
Very Inadequate	1	2
Don't Know	9	3

TABLE A-10

Maintainer Ratings of the Adequacy and Ease of Use of Tools

1. Type of tools and test equipment issued for performing direct support maintenance.

	Direct Support Maintainers (N=4)	OTEA Test Team (N=2)
Very Adequate	0	0
Adequate	3	1
Borderline	1	0
Inadequate	0	0
Very Inadequate	0	0
Don't Know	0	1

2. Ease in using the prescribed tools and test equipment.

	Direct Support Maintainers (N=4)	OTEA Test Team (N=2)
Very Adequate	1	0
Adequate	3	1
Borderline	0	0
Inadequate	0	0
Very Inadequate	0	0
Don't Know	0	1

3. Availability of the prescribed tools and test equipment.

	Direct Support Maintainers (N=4)	OTEA Test Team (N=2)
Very Adequate	1	0
Adequate	3	0
Borderline	0	0
Inadequate	0	1
Very Inadequate	0	0
Don't Know	0	1

TABLE A-11

Observations Concerning the Need for Test and Diagnostic Equipment in the Battery or Battalion

Have you noticed the need for any test and diagnostic equipment in the battery or battalion?

	Yes	No	Don't Know
FDO's	4	2	1
Battery Commanders	3	1	2
Battalion S3's	0	2	0
Battalion XO's	2	0	0
Battalion Commanders	1	0	1

TABLE A-12

BCU Operator and FDO Ratings of the
Adequacy and Ease of Use of Manuals

1. Rate the adequacy of the following manuals in each of the following areas.

	BCU Operators (N=14)						FDO's (N=7)					
	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't Know	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't Know
A. Operator's and Organizational Maintenance Manual (TM-11-7440-283-12-1).												
a. Completeness	0	7	2	1	0	4	0	2	2	1	0	2
b. Accuracy	0	7	1	1	0	4	0	2	3	0	0	2
c. Understandability	1	8	1	0	0	4	1	3	2	0	0	1
d. Ease of finding information	0	6	3	1	0	4	1	4	1	0	0	1
e. Clarity of diagrams	0	9	0	0	1	4	1	3	1	1	0	1
f. Clarity of flowcharts	0	6	0	0	1	7	0	3	1	1	0	2
B. User's Guide for BCS Software (UG-BCS01)												
a. Completeness	1	9	2	2	0	0	0	4	3	0	0	0
b. Accuracy	1	12	1	0	0	0	1	3	3	0	0	0
c. Understandability	1	10	3	0	0	0	2	3	1	1	0	0
d. Ease of finding information	0	8	3	0	3	0	1	4	1	1	0	0

TABLE A-12 (con't)

2. How easy or difficult was it to troubleshoot using the Operator's and Organizational Maintenance Manual?

	BCU Operators (N=14)	FDO's (N=7)
Very Easy	3	2
Easy	5	2
Borderline	3	3
Difficult	0	0
Very Difficult	0	0
Don't Know	3	0

Note: Total number of responses to each questionnaire item may differ because some respondents did not answer all questions.

TABLE A-13

Section Chief Ratings of the
Adequacy and Ease of Use of the Manual

Rate the adequacy of the Operator's and Organizational Maintenance Manual (TM 11-7440-283-12-2) in each of the following areas. (N=14)

Questionnaire Item	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't Know
a. Completeness	4	5	1	0	0	4
b. Accuracy	3	7	0	0	0	4
c. Understandability	5	3	2	0	0	4
d. Ease of Finding Information	4	5	1	0	0	4

TABLE A-14

Maintainer Ratings of the Adequacy
and Ease of Use of Manuals

1. Rate the adequacy of the following manuals in each of the following areas.

	Direct Support Maintainers (N=4)	Test Team Maintainers (N=2)
A. Operator's and Organizational Maintenance Manual (TM 11-7440-283-12-1)	Very Adequate / Adequate / Borderline / Inadequate / Very Inadequate / Don't Know	Very Adequate / Adequate / Borderline / Inadequate / Very Inadequate / Don't Know
1. Completeness	1 0 1 0 0 2	0 1 1 0 0 0
2. Accuracy	1 0 1 0 0 2	0 1 1 0 0 0
3. Understandability	1 1 0 0 0 2	0 1 1 0 0 0
4. Ease of finding information	1 1 0 0 0 2	0 1 0 1 0 0
5. Clarity of diagrams	1 1 0 0 0 2	0 1 1 0 0 0
6. Clarity of flowcharts	1 1 0 0 0 2	0 1 1 0 0 0
B. Direct Support Maintenance Manual (TM 11-7440-283-30)		
1. Completeness	0 0 1 1 0 2	0 0 1 0 1 0
2. Accuracy	1 1 0 0 0 2	0 1 1 0 0 0
3. Understandability	1 1 0 0 0 2	0 1 1 0 0 0
4. Ease of finding information	1 1 0 0 0 2	0 1 0 1 0 0
5. Clarity of diagrams	1 1 0 0 0 2	0 1 1 0 0 0
6. Clarity of flowcharts	1 0 0 0 0 2	0 1 1 0 0 0

TABLE A-14 (con't)

2. How adequate were troubleshooting procedures using the following manuals?

	Direct Support Maintainers (N=4)	Test Team Maintainers (N=2)
A. Operator's and Organizational Maintenance Manual (TM 11-7440-283-12-1)		
Very Adequate	0	0
Adequate	3	1
Borderline	1	1
Inadequate	0	0
Very Inadequate	0	0
Did Not Use	0	0
B. Direct Support Maintenance Manual (TM 11-7440-283-30)		
Very Adequate	0	0
Adequate	3	0
Borderline	0	2
Inadequate	0	0
Very Inadequate	0	0
Did Not Use	1	0

TABLE A-15

BCU Operator and FDO Ratings of the Ease or Difficulty in Performing Maintenance Procedures

Rate how easy or difficult it is to perform the following procedures:

	BCU Operators (N=14)						FDO's (N=7)					
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perfo
1. Performing Preventive Maintenance Checks and services.	1	10	1	0	0	2	4	2	0	0	0	1
2. Removal/Replacement of BCS Modules.	4	3	0	0	0	7	3	3	0	0	0	1
3. Replacement of BCS bulbs and knobs.	2	2	0	0	0	9	1	3	0	0	0	3

Note: Total number of responses to each questionnaire item may differ because some respondents did not answer all questions.

TABLE A-16

Section Chief Ratings of the Ease or
Difficulty in Performing Maintenance Procedures

Rate how easy or difficult it is to perform the following procedures:

	105mm Gun (N=4)						155mm Gun (N=12)					
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Assembly of GDU	2	2	0	0	0	0	5	2	3	0	1	1
2. Performing Preventive Maintenance Checks and Services.	3	1	0	0	0	0	2	5	1	0	0	4

TABLE A-17

Maintainer Ratings of the Ease or
Difficulty in Performing Maintenance Procedures

Rate how easy or difficult it is to perform each of the following procedures:

	DS Maintenance (N=4)						OTEA Test Team (N=2)					
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perfor
1. Remove/replace the Battery Computer Unit (BCU).	4	0	0	0	0	0	0	2	0	0	0	0
2. Remove/replace the Power Distribution Unit (PDU).	1	0	0	0	0	3	0	2	0	0	0	0
3. Remove/replace PDU lamps and batteries.	1	0	0	0	0	3	0	2	0	0	0	0
4. Adjust tension on keyboard latches.	1	0	0	0	0	3	0	2	0	0	0	0
5. Remove/replace BCU top cover and plug-in modules.	3	0	0	0	0	1	0	2	0	0	0	0
6. Remove/replace keyboard and external message lamps.	0	1	0	0	0	3	0	2	0	0	0	0
7. Remove/replace power supply.	0	1	0	0	0	3	0	1	1	0	0	0
8. Remove/replace tape electronics unit.	1	2	0	0	0	1	0	2	0	0	0	0
9. Remove/replace BCU front panel.	0	1	0	0	0	3	0	2	0	0	0	0
10. Repair front panel knobs and lamps.	0	1	0	0	0	3	0	1	0	0	0	1
11. Remove/replace "Electrical cables."	0	1	1	0	1	1	0	1	0	0	1	0

TABLE A-17 (con't)

	DS Maintenance (N=4)						OTEA Test Team (N=2)					
	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
12. Remove/replace PDU components.	0	0	0	0	0	4	0	1	0	0	0	1
13. Maintain BCS when mounted in M577A (Command Track).	1	2	1	0	0	0	0	2	0	0	0	0
14. Maintain BCS when mounted in M561 (Gamma Goat).	1	2	0	0	0	1	0	2	0	0	0	0

TABLE A-18

Safety Hazards Reported by Maintainers (N=6)

Type of Safety Hazard	Number of Complaints
1. Electrical Shock	0
2. Extreme Heat	0
3. Cuts and Abrasions	1

TABLE A-19

Ratings by BCU Operators, FDO's, Maintainers, Battery Commanders, and Battalion Command Group Personnel of the Availability of Replacement Parts

Rate the adequacy of the availability of replacement parts as specified in the prescribed load list (PLL) and the authorized stockage list (ASL).

	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't Know
BCU Operators (N=14)	2	2	0	2	0	8
FDO's (N=6)	0	2	3	1	0	0
DS Maintainers (N=4)	0	1	1	1	1	0
OTEA Test Team (N=2)	0	0	0	2	0	0
ASL Personnel (N=2)	0	1	1	0	0	0
Battery Commanders (N=6)	1	2	1	1	0	1
Battalion Commanders (N=2), XO's (N=2), and S3's (N=2).	0	1	2	3	0	0

TABLE A-20

Ratings of the BCS Logistical Support

Questionnaire Item:

1. Rate the adequacy of the overall logistical support concept for BCS.

Possible Response	Maintainers DS (N=4)	Maintainers OTEA (N=2)	FDO's (N=7)	Battery Commanders (N=6)	Battalion CO's/XO's/S3's (N=6)
Very Adequate	0	0	0	0	0
Adequate	2	0	5	3	3
Borderline	0	1	0	1	2
Inadequate	1	1	0	1	1
Very Inadequate	0	0	1	0	0
Don't Know	0	0	1	1	0

2. Based upon your observations during the field exercises of this test, have you noticed any of the following maintenance requirements?

a. The need for battery or battalion maintenance personnel other than the BCU operator to work on the BCS?

Yes		3	2	4
No		4	3	2
Don't Know		0	1	0

b. The need for a BCU maintenance MOS (separate from the TACFIRE MOS of 34Y)?

Yes	0	0	1	1	3
No	4	2	4	2	3
Don't Know	0	0	2	3	0

c. The need for more maintenance personnel (34Y)?

Yes	4	1
No	0	1
Don't Know	0	0

Note: Response frequencies may not sum to total number of respondents due to ommitted responses.

APPENDIX B

Questionnaires

QUESTIONNAIRE 1

OPERATOR

HUMAN FACTORS QUESTIONNAIRE FOR BATTERY COMPUTER UNIT (BCU) OPERATORS AND FDO'S

NAME _____ DATE _____

RANK _____

MOS _____

UNIT _____

The purpose of the following questionnaire is to obtain your opinions and observations about the adequacy of the BCS from an Operator's point of view. This will be accomplished by having you rate the adequacy of various aspects of the BCS, and by giving you the opportunity to make comments. Take as much time as you feel is necessary to accurately complete the questionnaire. The administrator will answer any questions you may have.

Did you attend the BCS course at Fort Sill?

_____Yes _____No

About how many hours have you operated the BCU during these 3 field exercises?

_____ 0 - 12

_____ 13 - 24

_____ 25 or more hours.

1. OPERATING THE EQUIPMENT

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Viewing the BCU visual display in daylight.						
2. Viewing BCU indicators in daylight.						
3. Operating the BCU keyboard in daylight.						
4. Operating BCU switches and controls in daylight.						
5. Viewing the BCU visual display at night.						
6. Viewing BCU indicators at night.						
7. Operating the BCU keyboard at night.						
8. Operating BCU switches and controls at night.						
9. Operating controls and switches of PDU during daylight.						
10. Operating controls and switches of PDU at night.						
11. Viewing indicators on PDU during daylight.						
12. Viewing indicators on PDU during daylight.						
13. Other (specify) _____						

Comments: _____

_____

_____

II. SYSTEM START-UP

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Installation of the BCU in its mount.						
2. Installation of the PDU in its mount.						
3. Installation of the KG-31 in it mount.						
4. Powering up.						
5. Loading program.						
6. Initialization/creation of a data base.						
7. Establish communication with subscribers						
a. By radio.						
b. By wire.						
8. Establish communication with GDU's						
a. By radio.						
b. By wire.						
9. BCU data base update for occupation of a new position.						
10. BCU data base (files) update during operation.						
11. Recording the data base.						
12. Restarting the system after a power failure.						
13. Other (specify) _____						

Comments: _____

_____

_____

11. Was the data that you entered into the system during initialization ever different from that required by your unit SOP?

Yes ____ No ____

If yes, please explain how it differed and why. _____

_____

III. MESSAGE TRANSMISSION AND COMMUNICATIONS

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Communicating by voice with GDU.						
2. Communicating digitally with GDU.						
3. Sending messages.						
4. Receiving messages.						
5. Understanding message formats.						
6. Authenticating messages manually.						
7. Serialization of messages using the KG-31.						
8. Understanding error and warning messages.						
9. Correcting errors.						
10. Other (specify) _____						

11. Are there ways to get around error messages without correcting them?

Yes ____ No ____

If yes, please explain how. _____

_____

_____

IV. PROCESSING FIRE MISSIONS

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform

1. Aborting a gun order computation. — — — — — —

2. Processing adjust fire missions using grid coordinates

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

3. Processing adjust fire missions using polar plots.

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

4. Processing adjust fire missions using shift from a known point

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

5. Processing precision registration fire missions (autonomous only). — — — — — —

6. Processing HB/MPI registrations (autonomous only). — — — — — —

7. Processing FFE fire missions

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

8. Processing FPF missions

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform

9. Processing Illumination missions.

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

10. Processing Laser missions

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

11. Processing Copperhead missions

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

12. Processing simultaneous fire missions

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

13. Processing Quick Smoke (screening) missions

   a. With TACFIRE. — — — — — —

   b. Autonomous. — — — — — —

14. Handing off fire missions to another BCU. — — — — — —

15. Reacting to checkfire. — — — — — —

16. Performing special computations (replot, MVV). — — — — — —

17. Processing fire missions from a previously stored fire plan. — — — — — —

18. Other (specify) _____ — — — — — —

Comments: _____

_____

19. Did you ever change the sheaf of a fire mission?

Yes ____ No ____

If yes, please explain the nature of the change, and why.

V. SYSTEM SHUT DOWN

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

- Very Easy
- Easy
- Borderline
- Difficult
- Very Difficult
- Did Not Perform

1. Powering down. _ _ _ _ _ _

2. Displacement (March ordering to a new position). _ _ _ _ _ _

Comments: _____

_____

_____

VI. NBC PROTECTIVE CLOTHING

Please indicate with a check mark ( ) how easy or difficult it is to perform the following operations while wearing an NBC protective mask and protective gloves.

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Viewing the BCU visual display.						
2. Viewing the BCU indicators.						
3. Viewing the BCU keyboard.						
4. Operating the BCU keyboard.						
5. Operating the BCU switches and controls.						
6. Other (specify) _____						

Comments: _____

_____

_____

VII. OPERATION IN AN EW ENVIRONMENT

1. Were you ever able to detect that BCS was being electronically jammed while operating with TACFIRE?

   Yes, definitely ___ Yes, I think so ___ No ___

   If yes, please explain what effects you noticed as a result of the jamming.

2. Were you ever able to detect that BCS was being electronically jammed while operating in the autonomous mode?

   Yes, definitely ___ Yes, I think so ___ No ___

   If yes, please explain what effects you noticed as a result of the jamming.

3. Were you ever able to detect that BCS was being electronically jammed while on the move?

Yes, definitely ___ Yes, I think so ___ No ___

If yes, please explain what effects you noticed as a result of the jamming.

4. Were you ever able to detect that a message you received through BCS was a false message (caused by enemy imitative deception)?

Yes, definitely ___ Yes, I think so ___ No ___

If yes, please explain how you were able to tell that the message was a false one.

VIII. MAINTENANCE

A. Procedures.

Use a check mark ( ) to indicate how easy or difficult it is to perform the following procedures:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Performing Preventive Maintenance Checks and Services.						
2. Troubleshooting using TM 11-7440-283-12-1 (Operator's and Organizational maintenance Manual).						
3. Performing the Self Diagnostic Test.						
4. Removal/Replacement of BCS modules.						
5. Replacement of BCS bulbs and knobs.						
6. Other (specify) _____						

Comments: _____

_____

_____

B. Tools, Parts, and Logistics Support

Use a check mark ( ) to indicate the adequacy of the following:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Type of tools and test equipment issued for performing organizational maintenance.						
2. Ease in using the prescribed tools and test equipment.						
3. Availability of the prescribed tools and test equipment.						
4. Availability of replacement parts (as specified in the Prescribed Load List and Authorized Stockage List).						
5. Other (specify) _____						

Comments: _____

_____

_____

15. TECHNICAL MANUALS

Using the scale to the right, indicate with a check mark ( ) the adequacy of the technical manuals in each of the following areas:

	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't Know
A. Operator's and Organizational Maintenance Manual (TM 11-7440-283-12-1)						
a. Completeness.						
b. Accuracy.						
c. Understandability.						
d. Ease of finding information.						
e. Clarity of diagrams.						
f. Clarity of flowcharts.						
g. Other (specify) _____						
B. User's Guide for BCS Software (UG-BCS)						
a. Completeness.						
b. Accuracy.						
c. Understandability.						
d. Ease of finding information.						
e. Other (specify) _____						

Comments: _____

_____

_____

X. SAFETY

Indicate with a check mark ( ) if you experienced any of the following safety hazards while operating the BCS.

1. Electrical Shock _____

2. Extreme Heat _____

3. Cuts or abrasions _____

4. Extreme Brightness _____

5. Extreme Loudness _____

6. Other (specify) _____ _____

Comments: _____

_____

_____

QUESTIONNAIRE 2

SECTION CHIEF

HUMAN FACTORS QUESTIONNAIRE FOR BCS SECTION CHIEFS

NAME _____ DATE _____

RANK _____

UNIT _____

1. About how many fire missions have you executed using the GDU during these field training exercises?

   0 - 10 ____
   11 - 30 ____
   31 - 50 ____
   More than 50 ____

2. What weapon did you work on during the field training exercises?

   a. M102 (105T) ____
   b. M109A2/3 (155 SP) ____
   c. M110A2 (8 SP) ____
   d. None ____

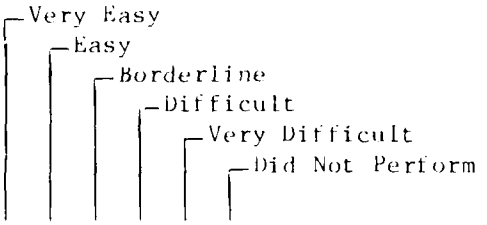
3. Did you receive classroom training on the GDU?

   Yes ____ No _____

The purpose of the following questionnaire is to obtain your opinions and observations about the adequacy of the GDU from a Section Chief's point of view. This will be accomplished by having you rate the adequacy of various aspects of the GDU and by giving you the opportunity to make comments. Take as much time as you feel is necessary to accurately complete the questionnaire. The administrator will answer any questions you may have.

1. GUN DIRECTION UNIT (GDU)

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:



1. Turn on/Turn off GDU. — — — — — —
2. Processing area fire missions. — — — — — —
3. Receiving updated fire data. — — — — — —
4. Processing final protective fire missions. — — — — — —
5. Processing other fire mission. (e.g., Copperhead, ICM) — — — — — —
6. Receiving special instructions, such as cease loading and check fire. — — — — — —
7. Viewing displays and controls during daylight. — — — — — —
8. Viewing displays and controls at night. — — — — — —
9. Viewing displays and controls while wearing NBC protective mask. — — — — — —
10. Operating controls while wearing NBC protective gloves. — — — — — —
11. Other (specify)_____ — — — — — —

12. How much confidence do you have in the accuracy of the fire commands which you receive through the section chief assembly without voice verification? — — — — — — —

Comments: _____

_____

II. MAINTENENACE

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Assembly of GDU.						
2. Performing preventive maintenance checks and services.						
3. Use of SELF TESTS.						
4. Other (specify) _____						

Comments: _____

_____

_____

III. TECHNICAL MANUAL

Using the scale to the right, rate the adequacy of the Operator's and Organizational Maintenance Manual (TM-11-7440-283-12-2(in each of the following areas:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Completeness.						
2. Accuracy.						
3. Understandability.						
4. Ease of finding information.						
5. Other (specify) _____						

Comments: _____

_____

_____

IV. SAFETY

Indicate with a check mark ( ) if you experienced any of the following safety hazards while operating the GDU.

1. Electrical shock. _____

2. Extreme Heat. _____

3. Cuts from the GDU. _____

4. Extreme Brightness. _____

5. Extreme Loudness. _____

6. Other (specify) _____ _____

Comments: _____

_____

QUESTIONNAIRE 3

GUNNER

HUMAN FACTORS QUESTIONNAIRE FOR BCS GUNNERS/ASST GUNNERS

NAME _____ DATE _____

RANK _____

UNIT _____

The purpose of the following questionnaire is to obtain your opinions and observations about the adequacy of the BCS from a Gunner's/Asst. Gunner's point of view. This will be accomplished by having you rate the adequacy of various aspects of the Gun Assemblies and by giving you the opportunity to make comments. Take as much time as you feel is necessary to accurately complete the questionnaire. The administrator will answer any questions you may have.

1. What weapon did you work on during the field exercise?

   a. M102 (105 T) _____

   b. M109A2/3 (155 SP) _____

   c. M110A2 (8 SP) _____

2. Which position did you work in most of the time?

   Gunner _____ Assistant Gunner _____

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
1. Reading gun assembly display during daylight.						
2. Reading gun assembly display during nighttime.						
3. Reading gun assembly display while wearing NBC protective mask.						
4. Other (specify) _____						

Comments: _____

_____

_____

5. Is the gun assembly positioned on the gun so that it is easy to use?

____ Yes

____ No

____ Gun assembly not mounted on gun.

If no, where should the gun assembly be located?

_____

_____

QUESTIONNAIRE 4

FDO

BCS QUESTIONNAIRE FOR FDO'S

NAME _____ DATE _____

RANK _____

UNIT _____

DUTY POSITION FOR BCS TEST _____

1. Based upon your past experiences and your observations of this test, rate the level of BCS knowledge and skill demonstrated by the following groups of individuals.

	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't Know
Battery Computer Unit Operators.	—	—	—	—	—	—
Howitzer Section Chiefs.	—	—	—	—	—	—
BCS Maintainers (Direct Support).	—	—	—	—	—	—

Comments: _____

_____

_____

2. Based upon your observations during the field exercises of this test, rate the adequacy of the prescribed load list (PLL) and the authorized stockage list (ASL) for BCS. — — — — — —

Comments: _____

_____

_____

3. Based upon your observations during the field exercises of this test, do you think that the following soldiers need certain specialized skills, in addition to those they received in MOS and BCS training, to effectively operate and maintain the BCS equipment?

a. Battery Computer Unit Operator (MOS 13E)

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

_____

b. Section Chief (MOS 13B)

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

c. Direct Support Maintenance (MOS 34Y)

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

4. Based upon your observations during the field exercises of this test, have you noticed any ot the following maintenance requirements?

a. The need for battery or battalion maintenance personnel other than the BCU operator to work on the BCS?

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

b. The need for a BCS maintenance MOS (separate from the TACFIRE MOS of 34Y)?

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

c. The need for any test and diagnostic equipment (TDE) in the battery or battalion?

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

5. Rate the adequacy of the overall logistical support concept for BCS.

Very adequate ____
Adequate ____
Borderline ____
Inadequate ____
Very inadequate ____

6. Based upon observation of your MOS 13E personnel, how well did the individual and collective training prepare them for the field exercises?

Very adequate ____
Adequate ____
Borderline ____
Inadequate ____
Very inadequate ____

7. Did you have to provide training in addition to that presented by Fort Sill instructors?

Yes _____ No _____

If yes, describe the nature and amount of training. _____

_____

_____

_____

_____

8. Did you train any MOS 13E personnel on the BCS who did not attend the individual training course at Fort Sill?

Yes _____ No _____

If yes, how many personnel and how difficult was it to train them?

_____

_____

_____

_____

9. Please comment on the strengths and weaknesses of the automated data system and its suppport.

_____

_____

QUESTIONNAIRE 5

MAINTAINER

HUMAN FACTORS QUESTIONNAIRE FOR BCS DIRECT SUPPORT MAINTAINERS

NAME _____ DATE _____

RANK _____

MOS _____

UNIT _____

The purpose of the following questionnaire is to obtain your opinions and observations about the adequacy of the BCS from a maintainers's point of view. This will be accomplished by having you rate the adequacy of various aspects of the BCS and by giving you the opportunity to make comments. Take as much time as you feel is necessary to accurately complete the questionnaire. The administrator will answer any questions you may have.

Did you receive classroom training at Fort Sill in BCS maintenance?

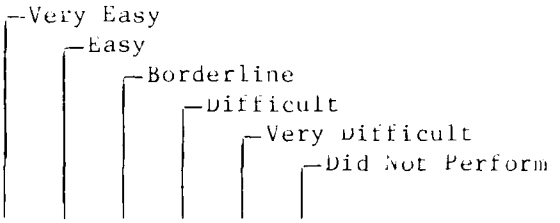
Yes _____ No _____

How much previous maintenance experience on TACFIRE do you have?

_____ months

I. TROUBLESHOOTING

Using the scale to the right, indicate with a check mark ( ) the adequacy of the following procedures:



1. Troubleshooting using TM 11-7440-283-12-1 (Operator's and Organizational Maintenance Manual). — — — — — —

2. Using Built-in Tests (BIT). — — — — — —

3. Using Operator-assisted diagnostic tests. — — — — — —

4. Troubleshooting using TM 11-7440-283-30 (Direct Support Maintenance Manual). — — — — — —

Comments: _____

_____

_____

II. EQUIPMENT REPLACEMENT AND REPAIR

Using the scale to the right, indicate with a check mark ( ) how easy or difficult it is to perform each of the following procedures:

1. Remove/replace the Battery Computer Unit (BCU). — — — — — —

2. Remove/replace the Power Distribution Unit (PDU). — — — — — —

3. Remove/replace PDU lamps and batteries. — — — — — —

4. Adjust tension on keyboard latches. — — — — — —

5. Remove/replace BCU top cover and plug-in modules. — — — — — —

	Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform
6. Remove/replace keyboard and external message lamps.	—	—	—	—	—	—
7. Remove/replace power supply.	—	—	—	—	—	—
8. Remove/replace tape electronics unit.	—	—	—	—	—	—
9. Remove/replace BCU front panel.	—	—	—	—	—	—
10. Repair front panel knobs and lamps	—	—	—	—	—	—
11. Remove/replace other BCU components (specify) _____	—	—	—	—	—	—
12. Remove/replace PDC components (specify) _____	—	—	—	—	—	—
13. Maintain BCS when mounted in M577A (Command Track).	—	—	—	—	—	—
14. Maintain BCS when mounted in M561 (Gamma Goat).	—	—	—	—	—	—

Comments: _____

_____

_____

III. TECHNICAL MANUAL

Using the scale to the right, indicate with a check mark ( ) the adequacy of the maintenance manuals in each of the following areas:

Very Adequate
Adequate
Borderline
Inadequate
Very Inadequate
Don't Know

A. Operators and Organizational Maintenance Manuals (TM-11-7440-283-12-1, 1).

1. Completeness.	—	—	—	—	—	—
2. Accuracy.	—	—	—	—	—	—
3. Understandability.	—	—	—	—	—	—
4. Ease of finding information.	—	—	—	—	—	—
5. Clarity of diagrams.	—	—	—	—	—	—
6. Clarity of flowcharts.	—	—	—	—	—	—
7. Other _____	—	—	—	—	—	—

B. Direct Support Maintenance Manual (TM 11-7440-283-30)

1. Completeness.	—	—	—	—	—	—
2. Accuracy.	—	—	—	—	—	—
3. Understandability.	—	—	—	—	—	—
4. Ease of finding information.	—	—	—	—	—	—
5. Clarity of diagrams.	—	—	—	—	—	—
6. Clarity of flowcharts.	—	—	—	—	—	—
7. Other _____	—	—	—	—	—	—

Comments: _____

_____

_____

IV. TOOLS, PARTS, AND LOGISTICS SUPPORT

Using the scale to the right, indicate with a check mark ( ) the adequacy of the following:

Very Easy	Easy	Borderline	Difficult	Very Difficult	Did Not Perform

1. Type of tools and test equipment issued for performing direct support maintenance (as specified in the Maintenance Manual, no special tools are required). — — — — — —

2. Ease in using the prescribed tools and test equipment. — — — — — —

3. Availability of the prescribed tools and test equipment. — — — — — —

4. Availability of repair and replacement parts (as specified in the Prescribed Load List [PLL] and Authorized Stockage Load [ASL]). — — — — — —

5. Overall logistics support concept. — — — — — —

Comments: _____

_____

_____

6. While maintaining both BCS and TACFIRE during this test, have you noticed any additional requirements in the following areas:

   a. The need for more maintenance personnel (34Y)?

      Yes _____ No _____ Don't Know _____

      If yes, please explain: _____

      _____

      _____

b. The need for a separate MOS for BCS maintainers?

Yes ____ No ____ Don't Know ____

If yes, please explain: _____

_____

_____

V. SAFETY

Indicate with a check mark ( ) if you experienced any of the following safety hazards while maintaining the BCS.

1. Elecrical Shock _____

2. Extreme Heat _____

3. Cuts and Abrasions _____

4. Other (specify) _____ _____

Comments: _____

_____

_____

QUESTIONNAIRE 6

ASL/PLL

HUMAN FACTORS QUESTIONNAIRE FOR ASL/PLL PERSONNEL

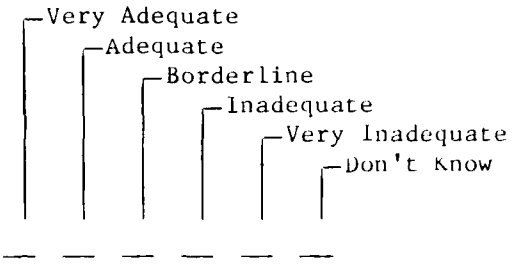
NAME _____ DATE _____

RANK _____

MOS _____

UNIT _____

1. Based upon your observation during the field exercises of the BCS test, use a check mark ( ) to indicate the adequacy of the prescribed load list (PLL) and the authorized stockage list (ASL) for BCS.



2. Please list any items which should be added to or deleted from the PLL/ASL.

ADD	DELETE

QUESTIONNAIRE 7

BATTERY COMMANDER

BCS QUESTIONNAIRE FOR BATTERY COMMANDERS

NAME _____ DATE _____

RANK _____

UNIT _____

How long have you been in command? _____

1. Based upon your past experience and your observations of this test, rate the level of BCS knowledge and skill demonstrated by the following groups of individuals.

	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't know
Battery FDO's	—	—	—	—	—	—
Battery Computer Unit Operators	—	—	—	—	—	—
Howitzer Section Chiefs.	—	—	—	—	—	—
BCS DS Maintainers.	—	—	—	—	—	—

Comments: _____

_____

_____

2. Based upon your observations during the field exercises of this test, rate the adequacy of prescribed load list (PLL) and the authorized stockage list (ASL) for BCS. — — — — — —

Comments: _____

_____

_____

3. Based upon your observations during the field exercises of th is test, do you think that the following soldiers need certain specialized skills, in addition to those they received in MOS and BCS training, to effectively operate and maintain the BCS equipment?

a. Battery Computer Unit Operator (MOS 13E)

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

_____

b. Section Chief (MOS 13B)

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

_____

4. Based upon your observations during the field exercises of this test, have you noticed any of the following maintenance requirements:

a. The need for battery or battalion maintenance personnel other than the BCU operator to work on the BCS?

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

b. The need for a BCS maintenance MOS (separate from the TACFIRE MOS of 34Y)?

Yes _____ No _____ Don't Know _____

c. The need for any test and diagnostic equipment (TDE) in the battery or battalion?

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

5. Rate the adequacy of the overall logistical support concept for BCS.

Very adequate ____
Adequate ____
Borderline ____
Inadequate ____
Very inadequate ____

6. Do Battery Commanders need formal training in BCS to perform as a commander?

   Yes _____ No _____

   If yes, what type of training and how much?

   _____

   _____

7. Has BCS caused a change in the way your unit operates?

   Yes _____ No _____

   If yes, comment on how.

   _____

   _____

   _____

8. Please comment on the strengths and weaknesses of the automated data system and its support. _____

   _____

   _____

   _____

   _____

9. Please comment on how BCS should be introduced to new units in the future. _____

   _____

   _____

   _____

   _____

QUESTIONNAIRE 8

BATTALION CO/S3

BCS QUESTIONNAIRE FOR BATTALION COMMANDERS/S3s

NAME _____ DATE _____

RANK _____

UNIT _____

How long have you been a commander/S3? _____

1. Based upon your past experiences and your observations of this test, rate the level of BCS knowledge and skill demonstrated by the following groups of individuals.

	Very Adequate	Adequate	Borderline	Inadequate	Very Inadequate	Don't Know
Battery FDO's	—	—	—	—	—	—
Battery Computer Unit Operators.	—	—	—	—	—	—
Howitzer Section Chiefs.	—	—	—	—	—	—
BCS DS Maintainers.	—	—	—	—	—	—

Comments: _____

_____

_____

2. Based upon your observations during the field exercises of this test, rate the adequacy of the prescribed load list (PLL) and the authorized stockage list (ASL) for BCS. — — — — — —

Comments: _____

_____

3. Based upon your observations during the field exercises of this test, do you think that the followiong soldiers need certain specialized skills, in addition to those they received in MOS and BCS training, to effectively operate and maintain the BCS equipment?

a. Battery Computer Unit Operator (MOS 13E)

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

b. Section Chief (MOS 13B)

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

4. Based upon your observations during the field exercises of this test, have you noticed any of the following maintenance requirements?

a. The need for battery or battalion maintenance personnel other than the BCU operator to work on the BCS?

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

b. The need for a BCS maintenance MOS (separate from the TACFIRE MOS OF 34Y)?

Yes _____ No _____ Don't know _____

If yes, please explain: _____

_____

c. The need for any test and diagnostic equipment (TDE) in the battery or battalion?

Yes _____ No _____ Don't Know _____

If yes, please explain: _____

_____

5. Rate the adequacy of the overall logistical support concept for BCS.

Very adequate ____
Adequate ____
Borderline ____
Inadequate ____

6. Is formal training in BCS necessary to perform as a commander/S3?

Yes _____ No _____

If yes, what type of training and how much?

_____

_____

7. Has BCS caused a change in the way your unit operates?

Yes _____ No _____

If yes, comment on how.

_____

_____

_____

8. Pleaase comment on the strengths and weaknesses of the automated data system and its support. _____

_____

_____

9. Please comment on how BCS should be introduced to new units in the future. _____

_____

_____