Research Report 1305

HUMAN FACTORS EVALUATION OF SELECTED STANO DEVICES EMPLOYED IN A MECHANIZED INFANTRY PLATOON

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U. S. Army

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This research was conducted as a human factors evaluation of four Surveillance, Target Acquisition, and Night Observation (STANO) devices which were undergoing operational testing at Fort Hood, Texas. The devices which were tested included the Platoon Early Warning System, the TOW Night Sight, the Dragon Night Tracker, and the Night Observation Device-Long Range. Rating forms and interviews were used to collect data related to the adequacy of controls and displays of the devices, the procedures needed for satisfactorily operating the devices,

psychological and physiological symptoms which were experienced while operating the devices, and safety hazards which were encountered. The most important finding concerned the problems which soldiers experienced in using the TOW Night Sight and the Dragon Night Tracker while wearing their protective masks.

RESEARCH
~~Technical~~ Report 1305

HUMAN FACTORS EVALUATION OF SELECTED STANO DEVICES EMPLOYED IN A MECHANIZED INFANTRY PLATOON

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Human Factors in Training
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FOREWORD

The modern Army is currently equipped with an unprecedented amount of equipment that incorporates a high degree of technological sophistication. Such equipment is extremely expensive and is only procured in rather limited quantities. Consequently it is essential that the capabilities of such equipment be exploited to the fullest extent at all times.

One of the factors which frequently prevents one from using equipment to its fullest capacity involves problems which occur at the interface between the piece of equipment itself and the individual who is operating it. When the man and the machine are not compatible, the machine cannot be used efficiently and its effectiveness on the battlefield is consequently reduced. In order to identify and help rectify such problems, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) frequently conducts human factors evaluations of selected Army equipment in an operational field test environment. The present human factors evaluation of selected STANO devices is one example of such efforts.

This research was conducted at Fort Hood, Texas, in the Spring of 1980 in conjunction with TRADOC Combined Arms Test Activity (TCATA) Field Test 426. Results from the present report were incorporated into the TCATA Field Test 426 Final Report entitled Mechanized Infantry in a Smoke Environment, which was used by the Infantry School in formulating and refining tactical doctrine concerning employment of STANO devices by infantry units.

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HUMAN FACTORS EVALUATION OF SELECTED STANO DEVICES EMPLOYED IN A MECHANIZED INFANTRY PLATOON

BRIEF

Requirement:

This research was conducted as a human factors evaluation of four Surveillance, Target Acquisition, and Night Observation (STANO) devices which were undergoing testing at Fort Hood, Texas. The devices which were tested included the Platoon Early Warning System, the TOW Night Sight, the Dragon Night Tracker, and the Night Observation Device - Long Range. The evaluation was part of Field Test 426, Mechanized Infantry in a Smoke Environment (MISE), conducted by the TRADOC Combined Arms Test Activity (TCATA) in the Spring of 1980. The results presented in the following report satisfied one of the objectives of the test; namely, to evaluate the STANO devices from a human factors perspective and identify any man-machine interface problems which existed.

Procedure:

Rating forms and interviews were used to collect data related to the adequacy of controls and displays of the devices, the procedures needed for satisfactorily operating the devices, psychological and physiological symptoms which were experienced while operating the devices, and safety hazards which were encountered. Average ratings, which were computed for each particular aspect of a device which was evaluated, and information obtained in the interviews, were used to identify specific man-machine interface problems and to identify ways of solving the problems in terms of changes in operating procedures, hardware design, or training procedures.

Principal Conclusions:

- The most serious problem identified involves the interface between the protective mask and both the TOW Night Sight and the Dragon Night Tracker. When a soldier uses his protective mask while operating either the TOW Night Sight or the Dragon Night Tracker, three problems emerge: 1) there is a substantial reduction in the sight picture in the device, 2) there is frequently a deforming of the protective mask itself which causes discomfort because of pressure being placed upon the area around the soldier's eye, and 3) glass inserts (worn by soldiers who must wear corrective lenses) frequently become twisted, dislodged, or pushed up against the soldier's face where they become covered with sweat and oil.

- Gunners of relatively short stature have difficulty using the TOW Night Sight because of the height at which it is mounted.

- Because of a lack of kinesthetic feedback concerning the various positions of the actuator switch on the thermal imaging devices (i.e. the TOW Night Sight, the Dragon Night Tracker, and the NODLR), there is a tendency among inexperienced personnel to rotate the switch too far and inadvertently release the coolant bottle on the device when attempting to merely shut the device off. This reduces the pressure within the coolant bottle and shortens its operating life, thus placing an added burden upon the logistical system.

- Many soldiers reported experiencing mild visual aftereffects after using the thermal imaging devices for as little as 20 or 30 minutes. However, these effects rapidly disappeared after ceasing to look through the devices.

Utilization of Findings:

The results of this research, in combination with the results from the other portions of the MISE field test conducted by TCATA, will be used by the Infantry School at Fort Benning, Georgia, to assist in formulating and refining tactical doctrine regarding the employment of the above STANO devices by infantry combat units. The results will also be used to assist in determining the design of future STANO equipment.

HUMAN FACTORS EVALUATION OF SELECTED STANO DEVICES EMPLOYED IN A MECHANIZED INFANTRY PLATOON

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INTRODUCTION

Recently the Army has begun to deploy several new types of surveillance, target acquisition, and night observation (STANO) devices. One of these devices, the Platoon Early Warning System (PEWS; AN/TRS-2), is sensitive to vibration and changes in soil conductivity and thus can be used to detect moving vehicles and moving personnel. The system is basically composed of nine detectors which a soldier emplaces at locations where an enemy is likely to cross but which are not directly observable by the soldier from his defensive position, and a receiver which can receive information from the sensors through either a wire link or by electromagnetic transmission. After emplacing the sensors the soldier merely monitors the receiver, either visually or aurally, to determine if there is enemy activity in the areas around which the sensors are emplaced. Current distribution of this system is one per infantry platoon.

Additional STANO devices which have recently been introduced include three thermal imaging devices which are sensitive to a narrow range of energy from the infrared (IR) portion of the electromagnetic spectrum. These devices include the night sight (AN/TAS-4) for the TOW weapon system, the night tracker (AN/TAS-5) for the Dragon Weapon System, and the Night Observation Device - Long Range (NODLR; AN/TAS-6), for use by commanders in observing the battlefield. All of these devices enable soldiers to detect objects in environments of reduced visibility, such as where there is no external light at night from either the moon or stars, or where visibility has been reduced by the presence of smoke. They have an advantage over earlier devices which also detected IR energy in that they do not require an active IR source to "illuminate" the object to be detected, but rather they passively detect small differences in the amount of IR energy emitted by an object compared to the amount emitted by its surrounding environment.

Currently, the planned basis of issue of these latter devices is one TOW night sight per TOW weapon system, one Dragon night tracker per Dragon weapon system, and one NODLR per mechanized infantry company.

Since the above devices provide the soldier with a capability which he has not had in the past, particularly in the ability to detect targets while in a smoke environment, the U.S. Army Infantry School (USAIS) requested that the TRADOC Combined Arms Test Activity (TCATA) conduct a test to examine the effects of employing these STANO devices on the capability of a mechanized infantry platoon to conduct offensive and defensive operations during periods of reduced visibility. The information obtained from such a test could be used by USAIS in formulating and refining doctrine for mechanized infantry units which were equipped with such STANO devices.

Among the test objectives which USAIS gave to TCATA was one which called for the identification of human factors implications resulting from the employment of the devices. The Army Research Institue (ARI) Field Unit at Fort Hood was asked by TCATA to fulfill the requirements of that particular test objective. This report represents the product of that effort and the results reported herein were incorporated into TCATA Test Report FT 426, Mechanized Infantry in a Smoke Environment (MISE).

METHODOLOGY

The MISE test (TCATA Field Test 426) was conducted at Fort Hood, Texas between 7 April and 13 June, 1980. Three reinforced mechanized infantry platoons each participated in a series of three 72-hour field training exercises that included conditions of varying visibility, viz. day clear, day with smoke, night clear, and night with smoke. Major tactical events which were conducted during each of the visibility conditions included tactical moves, hasty attacks, reconnaissance patrolling, occupation of defensive positions, defensive operations and disengagements. Most events were conducted against loosely structured aggressor arrays.

The human factors data that are included in the present report were collected only after the completion of either the second or third field training exercise in which a platoon was involved. This insured that the operators of the devices had adequate time in which to become familiar with them. The data were collected by means of structured interviews with operators of the devices. Each operator was first asked to complete a form which called for ratings of the adequacy of various aspects of the STANO device under the four conditions of visibility. Aspects of the devices which were listed in the forms (the appendix contains the form used to collect ratings on the TOW Night Sight; similar forms were used for the other systems) included the adequacy of controls (e.g. shape, size, spacing, labeling, etc.) as well as the adequacy of operating procedures (e.g. setting up and placing in operation, performing surveillance, tearing down, etc.) Also included were ratings of the extent to which various psychological or physiological symptoms were experienced when operating the devices, and the severity of any safety hazards that were encountered in the use of the devices. Ratings of the adequacy of characteristics of the devices made use of a five point scale (very adequate - 5, adequate - 4, borderline - 3, inadequate - 2, very inadequate - 1), while ratings of psychological/physiological effects and safety hazards utilized a four point scale (did not experience - 0, mildly severe - 1, moderately severe - 2, and extremely severe - 3).

After completing the rating form the operators were interviewed in order to obtain clarification of the ratings which they had given on the rating forms and to obtain any additional comments which an operator desired to make. The interviews were restricted to individuals designated as primary operators in each platoon and thus included three PEWS operators, six TOW night sight operators, ten Dragon night tracker operators, and five NODLR operators.

The rating data were analyzed by summing across operators and calculating an arithmetic mean for each characteristic of each device in each of the four visibility conditions. An average for all visibility conditions was also computed. The interview data were analyzed by noting the number of operators who made a given comment about a device and a composite of their comments was derived. The comments, or a composite of comments, are presented throughout the report to help clarify and explain operator ratings.

RESULTS AND DISCUSSION

Platoon Early Warning System (PEWS)

Illustrations of the PEWS receiver and sensor are shown in Figures 1 and 2. Mean ratings of the adequacy of the controls and display of the receiver are shown in Table 1, and mean ratings of the adequacy of the controls of the sensors are shown in Table 2. It can be seen that mean ratings within each visibility condition as well as averaged across visibility conditions ranged from 3.7 to 4.3. The ratings were all within the "adequate" region (3.5 to 4.5) of the rating scale.

Mean ratings of the adequacy of procedures for operating the PEWS are shown in Table 3. Only two of the procedures received less than "adequate" ratings. These included setting up and emplacing sensors under conditions of reduced visibility, and linking sensors to the receiver with wire under conditions of reduced visibility, both of which received ratings in the "borderline" (2.5 to 3.5) region. It should be noted, however, that these procedures involve more than just interfacing with the device itself; they also involve analyzing and traversing terrain in limited visibility. Such tasks are difficult to accomplish under most circumstances and thus are not unique to the PEWS.

Mean ratings of the severity of psychological and/or physiological symptoms which were experienced while operating the PEWS are shown in Table 4. It can be seen that some drowsiness was reported, as well as some muscle strain, ear discomfort, headache, and eyestrain. However, in the interviews the operators did not report that they experienced such effects. In retrospect it seems likely that the ratings which the PEWS operators gave to the various psychological and physiological symptoms listed in Table 4 were in reference to how they felt in general while participating in the test rather than as a result of using the PEWS per se. The test involved continuous operations over a 72 hour period. This would tend to make a soldier tired and lead to drowsiness, especially when he was engaged in a rather sedentary activity such as is involved in monitoring the PEWS. The test also involved simulated combat effects, such as smoke and artillery simulators, in an attempt to create a stressful and combat-like situation. Thus it is likely that the psychological and physiological symptoms reported were more a reflection of the effects of participating in a stressful test than a result of operating the PEWS. This conclusion is supported by the report of one of the PEWS operators that he was allergic to smoke and experienced discomfort whenever smoke was present.

Finally, only extreme loudness received a rating other than "did not experience" with respect to ratings of safety hazards. The overall average rating of .3 was caused by one individual who, when interviewed, said that he actually did not experience any loudness due to the PEWS itself. It is likely that the above rating was in reference to the conditions of the test (e.g. artillery simulators, etc.) rather than the PEWS per se.

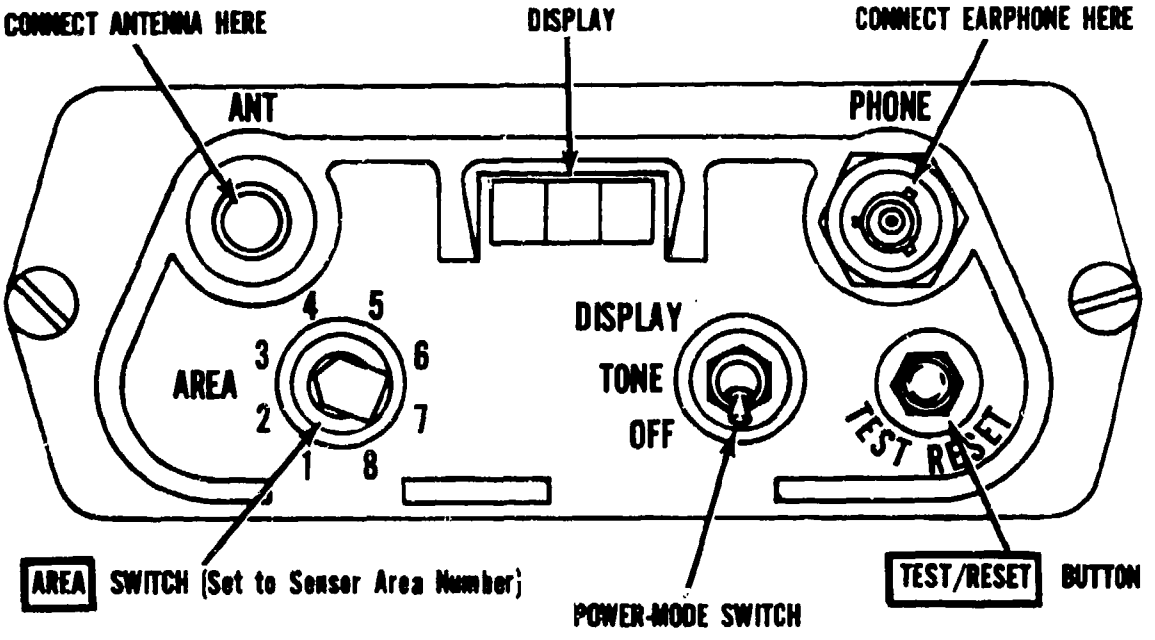

Figure 1. PEWS Receiver.

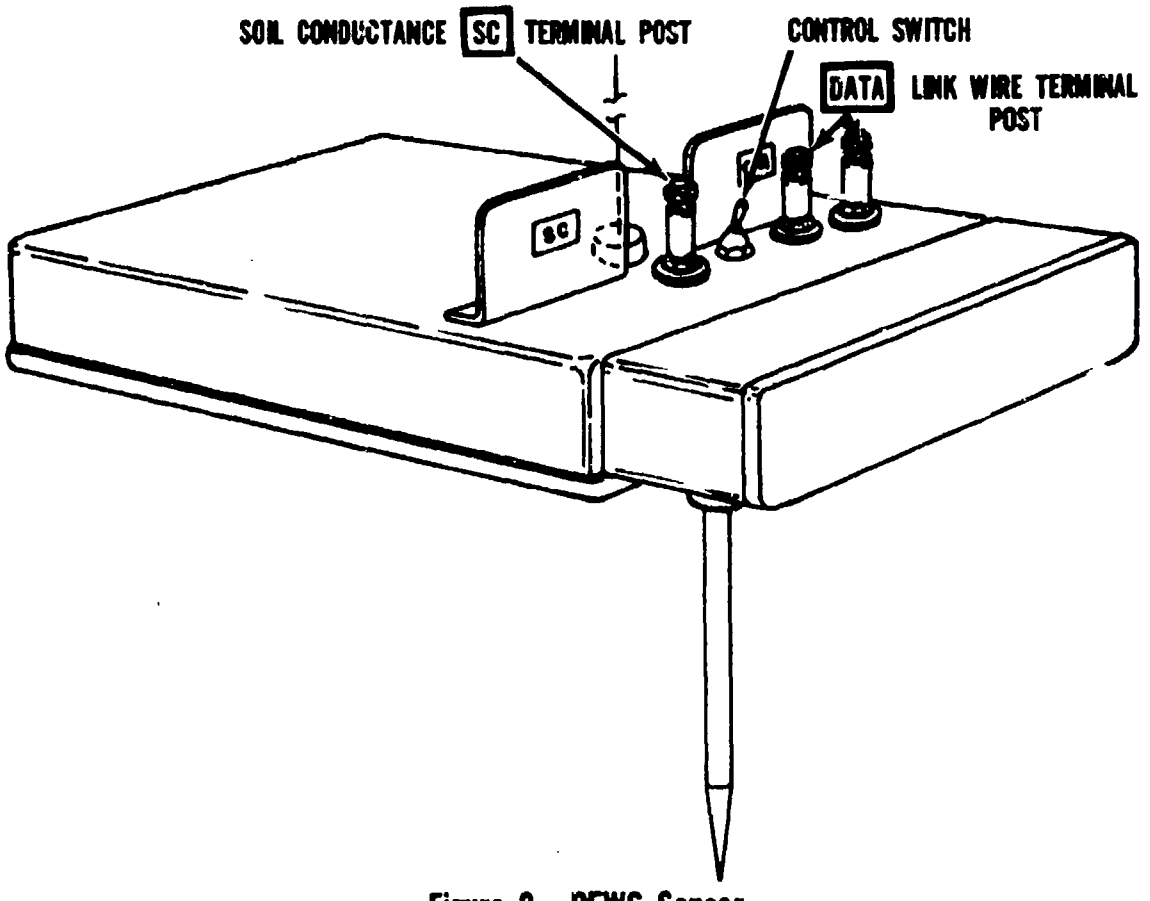

Figure 2. PEWS Sensor

TABLE 1

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE CONTROLS AND DISPLAY OF THE PEWS RECEIVER (n=3)

Control/display characteristics	Day	Day and smoke	Night	Night and smoke	Overall mean
Location of controls	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7
Understandable labels*					3.7
Absence of unrelated or confusing markings*					3.7
Shape (without gloves)	3.7 (.33)	3.7 (.33)	4.0 (.58)	4.0 (.58)	3.8
Shape (with gloves)	3.7 (.33)	3.7 (.33)	4.0 (.58)	4.0 (.58)	3.8
Spacing between controls (without gloves)	3.7 (.33)	3.7 (.33)	4.0 (.58)	4.0 (.58)	3.8
Spacing between controls (with gloves)	3.7 (.33)	3.7 (.33)	4.0 (.58)	4.0 (.58)	3.8
Size of labels	3.7 (.33)	3.7 (.33)	4.0 (.58)	4.0 (.58)	3.8
Size of controls (without gloves)	3.7 (.33)	3.7 (.33)	4.3 (.33)	4.3 (.33)	4.0
Size of controls (with gloves)	3.7 (.33)	3.7 (.33)	4.3 (.33)	4.3 (.33)	4.0
Resistance (too easy or hard to push or turn)	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0
Correct Labels*					4.0
Angle of view	4.0 (.00)	4.0 (.00)	4.0 (.00)	4.0 (.00)	4.0
Location of labels	4.0 (.00)	4.0 (.00)	4.3 (.33)	4.3 (.33)	4.2
Visibility of controls	4.3 (.33)	4.0 (.58)	4.3 (.33)	4.0 (.58)	4.2
Reach distance of controls	4.0 (.00)	4.0 (.00)	4.3 (.33)	4.3 (.33)	4.2
Functional grouping (controls with related functions grouped together)	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3

NOTE: Very adequate = 5; adequate = 4; borderline = 3; inadequate = 2; very inadequate = 1.

*Rating was only required for overall conditions.

TABLE 2

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE CONTROLS OF THE PEWS SENSORS (n=3)

Control/display characteristics	Day	Day and smoke	Night	Night and smoke	Overall mean
Resistence (too easy or too hard to push or turn)	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7
Correct Labels*					3.7
Understandable labels*					3.7
Absence of unrelated or confusing markings*					3.7
Spacing between controls (with gloves)	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7
Spacing between controls (without gloves)	3.7 (.33)	3.7 (.33)	4.0 (.58)	4.0 (.58)	3.8
Size of controls (without gloves)	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0
Size of controls (with gloves)	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0
Shape (with gloves)	3.7 (.33)	3.7 (.33)	4.3 (.33)	4.3 (.33)	4.0
Location of labels	3.7 (.33)	3.7 (.33)	4.3 (.33)	4.3 (.33)	4.0
Reach distance of controls	4.0 (.00)	4.0 (.00)	4.0 (.00)	4.0 (.00)	4.0
Shape (without gloves)	4.0 (.00)	4.0 (.00)	4.3 (.33)	4.3 (.33)	4.2
Size of labels	4.0 (.00)	4.0 (.00)	4.3 (.33)	4.3 (.33)	4.2
Functional grouping (controls with related functions grouped together	4.0 (.00)	4.0 (.00)	4.3 (.33)	4.3 (.33)	4.2
Visibility of controls	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3
Angle of view	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3
Location of controls	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate = 2, very inadequate = 1.

* Rating was only required for overall conditions.

TABLE 3

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF PROCEDURES FOR OPERATING THE PEWS (n = 3)

Procedure	Day	Day and smoke	Night	Night and smoke	Overall mean
Setting up and emplacing sensors	3.7 (.33)	3.3 (.33)	3.3 (.33)	3.0 (.00)	3.3
Linking sensors to receiver with wire	3.7 (.33)	3.3 (.33)	3.3 (.33)	3.0 (.00)	3.3
Testing the system	4.0 (.00)	4.0 (.00)	3.7 (.33)	4.0 (.00)	3.9
Shutting down and removing the system	4.3 (.33)	4.0 (.58)	4.0 (.58)	3.7 (.67)	4.0
Performing short term surveillance (two or more continuous hours)	4.3 (.33)	4.0 (.58)	4.3 (.33)	4.0 (.58)	4.2
Performing long term surveillance (two or more continuous hours)	4.3 (.33)	4.0 (.58)	4.3 (.33)	4.0 (.58)	4.2
Performing operator maintenance	4.3 (.33)	4.0 (.58)	4.3 (.33)	4.0 (.58)	4.2
Setting up the receiver	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3
Storing the system in the APC	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3 (.33)	4.3

NOTE: Very adequate = 5; adequate = 4; borderline = 3; inadequate = 2; very inadequate = 1.

TABLE 4

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE SEVERITY OF PSYCHOLOGICAL AND/OR PHYSIOLOGICAL SYMPTOMS EXPERIENCED WHILE OPERATING THE PEWS (n = 3)

Symptom	Day	Day and smoke	Night	Night and smoke	Overall mean
Drowsiness	.7 (.33)	1.0 (.58)	1.3 (.68)	1.0 (.58)	1.0
Muscle strain	.7 (.33)	1.0 (.58)	.7 (.33)	1.0 (.58)	.8
Ear discomfort	.7 (.33)	.7 (.33)	.7 (.33)	.7 (.33)	.7
Headache	.7 (.33)	.7 (.33)	.7 (.33)	.7 (.68)	.7
Eyestrain	.3 (.33)	1.0 (.58)	.3 (.33)	.7 (.67)	.6

NOTE: Did not experience = 0; Mildly severe = 1; moderately severe = 2; extremely severe = 3.

TOW Night Sight

The TOW Night Sight is illustrated in Figure 3. Mean ratings of the adequacy of the controls of the TOW Night Sight are shown in Table 5. The category of "spacing between controls, with gloves" received an overall rating of 3.3, which is in the "borderline" area. All other categories received overall ratings in the "adequate" region (3.5 to 4.5) or above. In the interviews it was revealed that the above problem primarily involved the brightness and contrast knobs, which were located relatively close together. Four of the five operators said that they sometimes confused these two knobs at night, and two of the operators stated that this was particularly true when they were wearing gloves. However, it should be noted that the consequences of confusing the two knobs is quickly recognized in the sight picture and such an error can be rapidly and easily corrected. Thus, this problem is not one of major significance.

A problem with the controls which was not revealed in the ratings but did appear in the interviews involved operating the actuator switch. Three of the six operators that were interviewed stated that there was a tendency to rotate the switch too far when attempting to merely turn the sight off, thus releasing the coolant bottle and causing a loss of air pressure in the bottle. The basic problem here appears to be that there is a lack of sufficient kinesthetic feedback for indicating switch positions. The switch is a four-position switch. When it is in the "on" position, the night sight is operational. To turn the sight off, one must turn the switch clockwise to the "air battery check" position and then to the "off" position. If it is turned past the "off" position, the switch goes into the "release" position and releases the coolant bottle from its coupling, thus allowing air to escape from the bottle with the result that the bottle frequently has to be replaced with a freshly filled one. This adds to the logistical burden involved in keeping a supply of bottles with the devices. Although with time and experience the operators learned to identify the switch positions by kinesthetic feedback alone, future design of such equipment should take this finding into account and provide better feedback on such switches. Spring loading the release position of the switch so that extra effort is necessary to place the switch into the "release" position is one possible remedy to the problem.

Mean ratings of the adequacy of the controls of the boresight collimator are shown in Table 6. All average ratings were in the "adequate" range (3.5 to 4.5) or better, thus revealing no problem with the collimator from a human factors perspective.

Table 7 shows the average ratings given to the adequacy of the procedures needed for operating the night sight. As with the boresight collimator, all of the mean ratings were in the "adequate" range (3.5 to 4.5) or better. However, a number of problems were revealed in the interviews with the operators. The most serious problem involved the use of the protective mask while operating the TOW Night Sight. Five of the six operators interviewed indicated that they had problems in this area. Two of these gunners were issued the M25 series protective mask (known as the tanker's mask) which has a

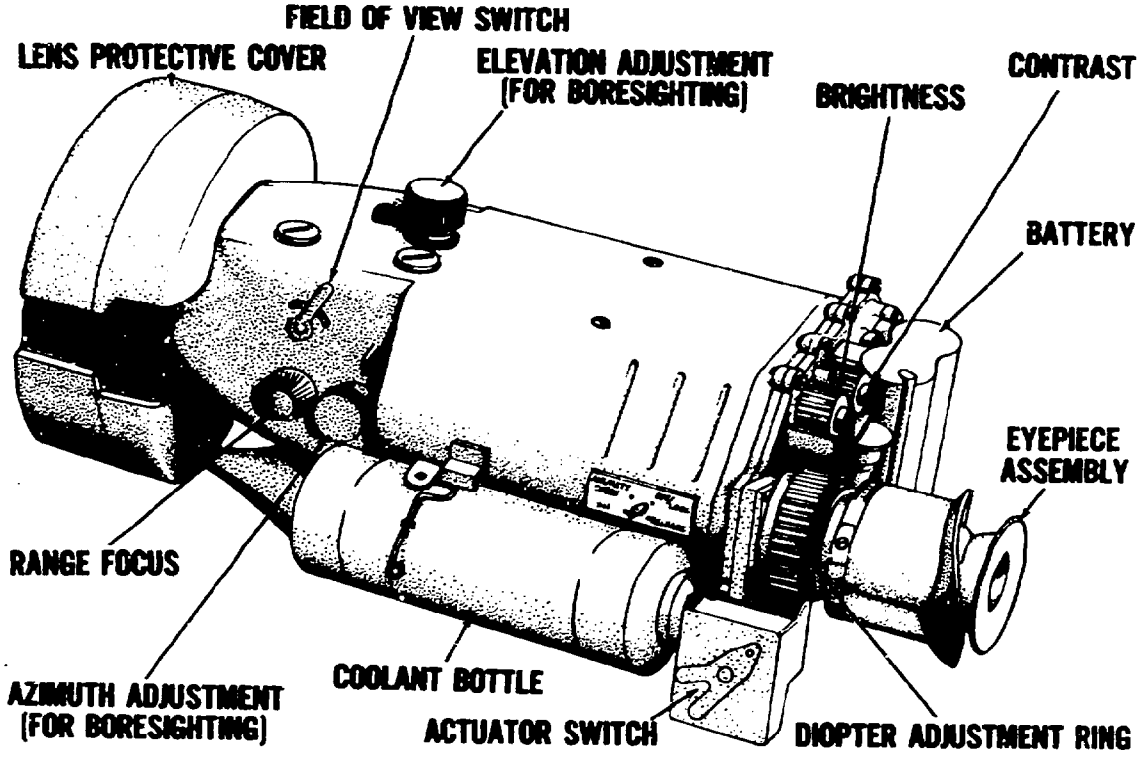

Figure 3. TOW Night Sight.

TABLE 5

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE CONTROLS OF THE TOW NIGHT SIGHT (n = 6)

Control characteristics	Day	Day and smoke	Night	Night and smoke	Overall mean
Spacing between controls (with gloves	3.8 (.48)	3.2 (.25)	3.2 (.25)	3.0 (.00)	3.3
Size of labels	4.5 (.22)	4.0 (.25)	4.0 (.45)	3.5 (.56)	4.0
Location of labels	4.5 (.21)	4.0 (.26)	3.8 (.40)	3.7 (.42)	4.0
Absence of unrelated or confusing markings*					4.0
Correct labels*					4.2
Angle of view	4.3 (.21)	4.0 (.26)	4.3 (.21)	4.0 (.26)	4.2
Visibility of controls	4.5 (.22)	4.2 (.17)	4.2 (.31)	4.0 (.26)	4.2
Understandable labels*					4.3
Location of controls	4.5 (.22)	4.2 (.17)	4.3 (.21)	4.2 (.17)	4.3
Shape (without gloves	4.5 (.34)	4.3 (.33)	4.5 (.22)	4.2 (.31)	4.4
Shape (with gloves)	4.5 (.50)	4.5 (.50)	4.5 (.50)	4.2 (.48)	4.4
Spacing between controls (without gloves)	4.5 (.22)	4.5 (.22)	4.5 (.22)	4.3 (.21)	4.4
Reach distance of controls	4.7 (.21)	4.3 (.21)	4.5 (.22)	4.3 (.21)	4.4
Size (without gloves)	4.5 (.22)	4.5 (.22)	4.7 (.21)	4.2 (.31)	4.5
Size (with gloves)	4.5 (.29)	4.8 (.25)	4.8 (.25)	4.2 (.25)	4.5
Resistence (too easy or too hard to push or turn)	4.5 (.34)	4.5 (.34)	4.5 (.34)	4.5 (.34)	4.5
Functional grouping (controls with related functions grouped together)	4.7 (.21)	4.5 (.22)	4.7 (.21)	4.5 (.22)	4.6

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate = 2, very inadequate = 1.

*Rating was made only for overall conditions.

TABLE 6

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE CONTROLS OF THE BORESIGHT COLLIMATOR FOR THE TOW NIGHT SIGHT (n = 6)

Control characteristics	Day	Day and smoke	Night	Night and smoke	Overall mean
Absence of unrelated of confusing markings*					4.0
Size of labels	4.3 (.33)	4.0 (.45)	4.2 (.48)	3.8 (.49)	4.1
Size of controls (with gloves	4.2 (.48)	4.0 (.58)	4.2 (.48)	4.0 (.58)	4.1
Shape (with gloves	4.2 (.48)	4.0 (.58)	4.2 (.48)	.40 (.58)	4.1
Angle of view	4.3 (.33)	4.0 (.36)	4.3 (.33)	3.8 (.37)	4.1
Spacing between control (with gloves)	4.5 (.29)	4.0 (.58)	4.2 (.48)	4.0 (.58)	4.2
Shape (without gloves)	4.3 (.33)	4.2 (.31)	4.3 (.33)	4.0 (.32)	4.2
Resistance (too easy or too hard to push or turn)	4.3 (.21)	4.2 (.17)	4.3 (.21)	4.0 (.00)	4.2
Location of labels	4.5 (.22)	4.3 (.21)	4.3 (.33)	4.0 (.49)	4.3
Functional grouping (controls with related functions grouped together)	4.5 (.22)	4.3 (.21)	4.5 (.22)	4.2 (.20)	4.4
Location of controls	4.7 (.21)	4.5 (.22)	4.5 (.22)	4.2 (.20	4.5
Visibility of controls	4.8 (.17)	4.5 (.22)	4.5 (.22)	4.2 (.20)	4.5
Spacing between controls (without gloves)	4.7 (.21)	4.5 (.24)	4.5 (.21)	4.2 (.24)	4.6
Size of controls (without gloves)	4.7 (.21)	4.5 (.22)	4.7 (.21)	4.5 (.24)	4.6
Reach distance of controls	4.7 (.21)	4.7 (.21)	4.7 (.21)	4.6 (.24)	4.7
Correct labels*					4.7
Understandable labels*					4.7

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate = 2, very inadequate = 1.

*Rating was only required for overall conditions.

TABLE 7

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE OPERATING PROCEDURES FOR THE TOW NIGHT SIGHT (n = 6)

Procedure	Day	Day and smoke	Night	Night and smoke	Overall mean
Performing long-term surveillance (two or more continuous hours)	4.5 (.22)	4.0 (.26)	4.3 (.21)	3.8 (.31)	4.2
Performing operator maintenance	4.8 (.17)	3.7 (.42)	4.7 (.21)	3.7 (.42)	4.2
Installing the night sight	4.7 (.21)	4.7 (.21)	4.5 (.22)	4.0 (.32)	4.5
Performing short-term surveillance (less than two continuous hours)	4.7 (.21)	4.3 (.33)	4.7 (.21)	4.3 (.33)	4.5
Collimating the night sight	4.7 (.21)	4.5 (.22)	4.5 (.22)	4.5 (.24)	4.6
Storing the night sight and case in the APC	4.7 (.21)	4.5 (.22)	4.5 (.22)	4.5 (.22)	4.6
Connecting the night sight to the vehicle power conditioner	4.7 (.21)	4.7 (.21)	4.7 (.21)	4.7 (.21)	4.7
Tracking a target with the night sight	4.7 (.21)	4.7 (.21)	4.8 (.17)	4.8 (.17)	4.8
Replacing batteries	4.8 (.17)	4.8 (.17)	4.8 (.17)	4.7 (.21)	4.8
Removing the night sight from the launcher	4.8 (.17)	4.8 (.17)	4.8 (.17)	4.7 (.21)	4.8
Storing the night sight in the field handling case	4.8 (.17(	4.8 (.17)	4.8 (.17)	4.7 (.21)	4.8
Replacing coolant bottles	4.8 (.17)	4.8 (.17)	4.8 (.17)	4.8 (.17)	4.8

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate =2, very inadequate = 1.

single-piece eye shield. These two gunners complained of uncomfortable presssure around the eye, sometimes causing tearing and blurriness, and restriction of the field of view through the sight when operating the night sight with the M25 mask donned. The other three gunners were issued the M17 series protective mask with a two-piece eye shield. These gunners also complained of a restriction of the field of view through the sight when wearing the mask. In addition, one of these gunners complained about the sweat which accumulated while wearing the mask. The same gunner also complained that in one smoke condition when viewing through the sight the pressure of the eyepiece of the mask against the eyepiece assembly of the sight caused a break in the seal between the mask and his face, thus allowing a small amount of smoke to enter his mask. Finally, one of the gunners with the M17 series mask, who wore glasses and thus had optical inserts for use with the mask, complained that pushing against the eyepiece assembly of the night sight while wearing his mask caused twisting and dislodging of his optical inserts, thus making it difficult to use the night sight.

Most of the above problems revolve around the fact that in order to open the shutter of the eyepiece assembly of the night sight, one must position his eye in the center of the eyepiece and press forward. Without the protective mask, this creates little problem; but with the protective mask a number of problems emerge. First, the eye shield of the mask prevents the operator from bringing his eye close enough to the sight picture inside the night sight to obtain the maximum field of view. Instead, the eye is held back a short distance and the amount of the sight picture that can actually be seen is reduced, laterally, by roughly 40 percent (the effect is much like that experienced when trying to look through a pair of binoculars held an inch or so away from one's eyes). With the narrow field of view this results in a substantial reduction in an operator's ability to search for and track targets at long ranges.

A second problem with the protective mask involves the fact that the pressure which must be exerted against the eyepiece assembly in order to see through the device causes the eye shield of the M25 series protective mask to deform and put pressure upon the area around the eye itself. The resulting discomfort, tearing and visual blurriness would be expected to degrade gunner performance, if not over a short period of operation, then during long periods of continuous operations. The two gunners who used the M25 series protective mask with the night sight complained strongly about this in the interviews and thus this is a problem that warrants attention in the design of future masks.

The M17 series protective mask did not appear to have a problem with deformation of the eye shields, probably because the design of the mask involves a separate eye shield over each eye, thus providing a much stronger surface for resisting pressure from the eyepiece assembly. However, such pressure did cause a problem in that it forced the whole mask farther back onto the operator's face, thus causing the glass inserts (which individuals who normally wear corrective lenses must use in their mask) to become twisted in the mask, released from their proper position in the mask, or pushed up against the wearer's face and consequently covered with sweat and oil. All of these consequences hinder an operator who needs corrective lenses from effectively using the TOW Night Sight while wearing a protective mask.

The final problem associated with the use of the protective mask involved the report from one gunner of smoke getting in his mask because the pressure he was exerting against the night sight eyepiece assembly caused enough distortion in his M17 mask to break the seal around his face. This problem, although only reported by one of the six gunners interviewed, is potentially severe enough to warrant further research and investigation because a leak in the gas mask in a chemical environment will likely terminate a gunner's performance, rather than just degrade it.

Another major problem which came to light in the interviews concerned the height of the TOW night sight. Four of the six operators that were interviewed said that this was a problem for short gunners. Two gunners, who said that they were 5'7" tall, claimed that they could not see through the TOW Night Sight unless standing on their tiptoes or standing on a support like a water can or tool bag. Two other gunners, who claimed to be 5'10" and 6'0" tall, felt that the level of the TOW Night Sight was just right for them. The problem here derives from the fact that the TOW Night Sight is mounted on top of the TOW Day Sight, thus placing it a good six inches higher than the day sight which is set at a satisfactory height for most gunners. Furthermore, the platform on which the gunner stands when manning the gun and sight is not adjustable. The result is that gunners who are shorter than approximately 5'10" have a problem using the night sight, unless they stand on their tip toes, which becomes strenuous after a short period of time, or stand on something like a water can or tool bag. Unfortunately, using water cans and tool bags for this purpose precludes their being used for the purposes for which they were designed, and also results in a rather unsteady platform. Another alternative, and one which was frequently used on the test, is for the gunner to position himself on top of the TOW vehicle around the edge of the cargo hatch and brace himself with his feet and legs. This, however, has a serious disadvantage in that the gunner's body is then fully exposed to artillery shrapnel. In a combat environment, a gunner would want to protect as much of his body as he could. This is a problem which would appear to merit the immediate attention of vehicle designers because short gunners have serious problems in using the night sight in a combat environment. Designing the platform inside the TOW vehicle so that it can be adjusted up another six inches would solve this problem.

Another problem related to operating procedures concerned using the device in the rain. Two of the operators stated that the training which they had received (from personnel detached from the Infantry School) suggested not using the night sight in the rain. However, the test director wanted the devices used in the rain and so informed the operators of the devices. This produced a conflict among the operators in that they felt that they were being asked to do something which could possibly damage the sight. In reality, getting moisture on the lens of the devices will not damage them, although it will reduce their effectiveness. Furthermore, such moisture should only be removed by using a special cleansing solution issued with the devices in order to avoid scratching or otherwise marring the surface of the lens. This problem is one which, it would seem, can be easily solved through proper training.

Finally, five of the six operators that were interviewed stated that the normal position of their helmet prevented them from looking through the TOW Day Sight when the TOW Night Sight was mounted because the bill of the helmet collided with the body of the Night Sight. The operators easily solved this problem, however, by merely tilting the helmet back.

Mean ratings of the severity of psychological and/or physiological symptoms experienced while operating the TOW Night Sight are shown in Table 8. It can be seen that the overall ratings ranged from .8 ("mildly severe") for eyestrain to 0.0 ("did not experience") for drowsiness. During the interviews all six of the TOW Night Sight operators stated that they had experienced some visual difficulties when looking through the night sight over a period of time. Estimates varied from 10 minutes to 34 minutes in terms of the length of time of continuous viewing before the onset of the symptoms. All of these symptoms were reported to have gone away within a few seconds or minutes after ceasing to look through the device. The descriptions of the symptoms involved blurred vision and afterimages. Examples of descriptions are: "You see a little bit blurry, but in about five seconds or so it will clear up;" "At day I'll look through (the sight), then I'll step back off it. I won't see no colors or anything; just have to blink a few times, and I can get back on it. At night I'll blink, but I'll see flashes with red colors;" and, "You see the red and black (as in the sight picture). Have you ever been hit real hard? Your vision gets blurred a little. That's basically the same thing you get."

Other psychological and physiological effects reported by three of the operators during the interviews included burning eyes, dizziness, and muscle strain. The first two symptoms were attributed by the operators to the heat, smoke, and fatigue experienced during the test, rather than to the act of observing through the TOW Night Sight. The third symptom, muscle strain, was attributed to having to stand or prop oneself up behind the TOW gun and night sight for relatively long periods of time while using the night sight.

Thus, although the results from the rating scale of psychological and physiological symptoms indicated that some of the operators experienced in a mild way a number of different symptoms, the comments in the interviews indicated that the major symptom from using the TOW Night Sight concerned blurred vision and afterimages, from which recovery was very rapid for both. Other symptoms, such as burning eyes and dizziness were possibly due to the environmental and test conditions themselves rather than the TOW Night Sight.

With respect to safety hazards which operators experienced with the TOW Night Sight, only the factor of extreme brightness received anything other than a "did not experience" rating. The overall average rating of .2 for this category resulted from "mildly severe" rating by one operator.

In the interviews, two operators, one of which gave the "mildly severe" rating to the extreme brightness category, indicated that when one switches from the narrow field of view to the wide field of view, the image inside the TOW Night Sight becomes brighter. The visual aftereffect was described as similar to the afterimage experienced by an individual when he is exposed to a bright flash of light at night. However, neither of the operators indicated that it hurt or was painful to their eyes. Thus, it seems reasonable to assume that this was not a safety hazard.

TABLE 8

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE SEVERITY OF PSYCHOLOGICAL AND/OR PHYSIOLOGICAL SYMPTOMS EXPERIENCED WHILE OPERATING THE TOW NIGHT SIGHT (n = 6)

Symptom	Day	Day and smoke	Night	Night and smoke	Overall mean
Eye strain	.7 (.33)	.6 (.40)	1.0 (.55)	1.0 (.55)	.8
Blurred vision while looking through the sight	.3 (.21)	.8 (.31)	.7 (.21)	.8 (.31)	.7
Tearing of eyes	.5 (.22)	.7 (.21)	.5 (.22)	.7 (.21)	.6
Dizziness	.5 (.34)	.5 (.34)	.5 (.34)	.5 (.34)	.5
Blurred vision after looking through the sight	.3 (.21)	.3 (.21)	.5 (.34)	.5 (.34)	.4
Burning eyes	.2 (.17)	.3 (.21)	.3 (.21)	.5 (.22)	.3
Difficulty focusing eyes	.3 (.21)	.3 (.21)	.3 (.21)	.3 (.21)	.3
Muscle strain	.2 (.17)	.2 (.17)	.2 (.17)	.2 (.17)	.2
Headache	.3 (.33)	.3 (.33)	0.0 (.00)	0.0 (.00)	.2
Nausea	0.0 (.00)	.2 (.17)	0.0 (.00)	.2 (.17)	.1
Drowsiness	0.0 (.00)	0.0 (.00	0.0 (.00)	0.0 (.00)	0.0

NOTE: Did not experience = 0, mildly severe = 1, moderately severe = 2, extremely severe = 3.

Dragon Night Tracker

The Dragon Night Tracker is illustrated in Figure 4. Overall mean ratings of the adequacy of the controls, shown in Table 9, ranged from 3.7 for the size of the controls while the operator was wearing gloves to 4.7 for the resistance of the controls. All of these ratings were in the "adequate" (3.5 to 4.5) or "very adequate" (4.5 to 5.0) range.

Similarly, the overall mean ratings (shown in Table 10) of the adequacy of the procedures needed for operating the Dragon Night Tracker ranged from 3.8 to 4.8. All of these ratings were in the "adequate" (3.5 to 4.5) range or above. However, in the interviews a number of problems surfaced.

The most serious problem which appeared concerned use of the protective mask while using the night tracker. The complaints were similar to those made by the TOW Night Sight operators. Out of ten Dragon Night Tracker operators who were interviewed, seven felt that the protective mask presented a problem. Of two operators who were issued the M25 series protective mask (which has a single eye shield), one complained that the eye shield collapsed inward when pressure was exerted against the eyepiece assembly of the Dragon Night Tracker, thus pressing against his eyelid, causing him a certain amount of discomfort and preventing him from adequately using the device. The other operator said that his major problem with the M25 series mask was that the eye shield prevented him from bringing his eye close enough to the eyepiece assembly to clearly focus the lens with the diopter ring. The remaining five operators who complained about the mask were issued the M17 series protective mask with a separate eye shield for each eye. The complaints from these individuals included not being able to get close enough to the eyepiece assembly to see the full sight picture, and the problem of sweat accumulating in the mask and getting in one's eye while one is trying to look through the tracker. One of the operators used corrective lens inserts with the mask and complained that they were pushed up against his eyelid when he tried looking through the tracker, making him somewhat uncomfortable.

It thus appears that the problem was somewhat more severe for those two individuals who used the M25 mask, although the complaints made by those soldiers with the M17 mask indicate that it was far from ideal. The problem is especially salient with individuals who wear corrective lenses and must use the optical lens inserts in their protective masks. It would appear that such individuals should be utilized as gunners only in a secondary role since the discomfort involved with using the protective mask with the glass inserts in conjunction with using Dragon Night Tracker could cause a substantial degradation in target acquisition and tracking performance.

Overall mean ratings of the severity of psychological and/or physiological symptoms which were experienced while operating the Dragon Night Tracker, shown in Table 11, ranged from .8 ("mildly severe") for difficulty in focusing eyes to .2 (close to "did not experience") for dizziness and nausea. Information obtained in the interviews supported these ratings in showing that visual effects were the most serious problem.

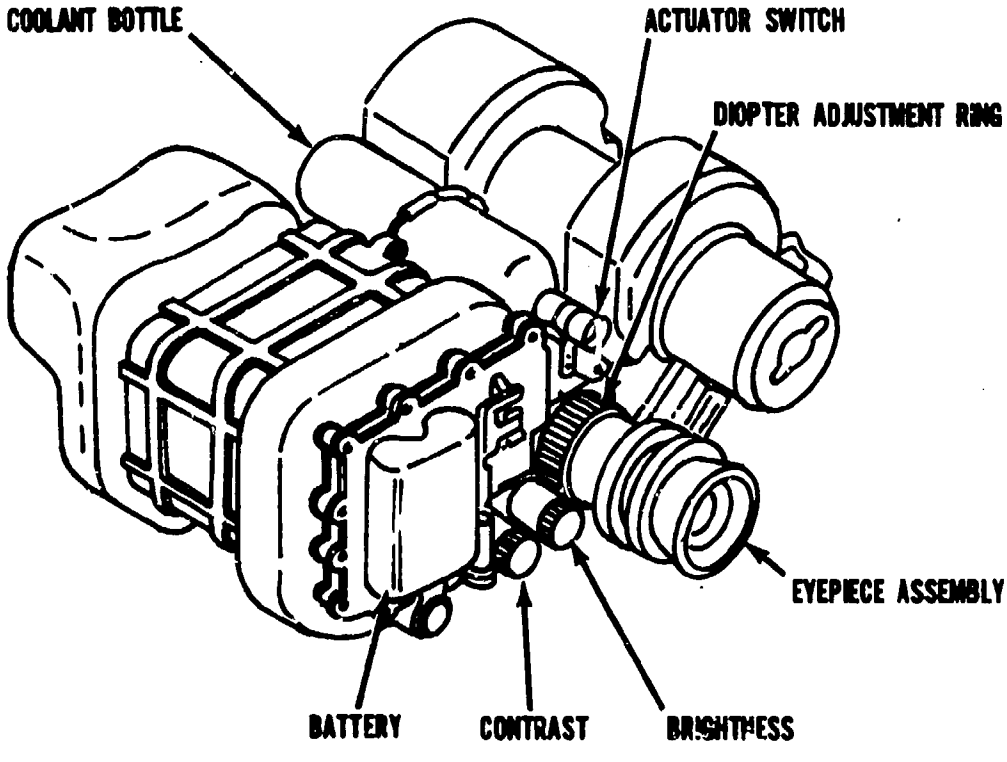

Figure 4. Dragon Night Tracker.

TABLE 9

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE CONTROLS OF THE DRAGON NIGHT TRACKER (n = 10,

Control characteristics	Day	Day and smoke	Night	Night and smoke	Overall mean
Size of controls (with gloves)	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7 (.33)	3.7
Spacing between controls (with gloves)	3.7 (.88)	3.7 (.88)	3.7 (.88)	3.7 (.88)	3.7
Absence of unrelated or confusing markings*					3.7
Shape (with gloves)	4.0 (.38)	4.0 (.58)	3.7 (.33)	3.7 (.33)	3.9
Understandable labels*					4.1
Location of controls	4.4 (.31)	4.2 (.33)	4.1 (.28)	3.8 (.29)	4.1
Size of labels	4.4 (.18)	4.2 (.22)	4.1 (.20)	4.0 (.24)	4.2
Location of labels	4.5 (.17)	4.2 (.22)	4.2 (.22)	3.9 (.20)	4.2
Spacing between controls (without gloves	4.2 (.25)	4.4 (.22)	4.4 (.27)	4.1 (.28)	4.3
Correct labels*					4.3
Reach distance of controls	4.5 (.17)	4.3 (.21)	4.4 (.16)	4.1 (.23)	4.3
Angle of view	4.6 (.16)	4.4 (.22)	4.4 (.22)	4.1 (.23)	4.4
Shape (without gloves	4.4 (.22)	4.5 (.24)	4.6 (.22)	4.2 (.25)	4.5
Size of controls (without gloves)	4.5 (.17)	4.6 (.16)	4.6 (.22)	4.2 (.25)	4.5
Visibility of controls	4.7 (.15)	4.5 (.22)	4.7 (.15)	4.3 (.26)	4.6
Functional grouping (controls with related functions grouped together	4.8 (.13)	4.6 (.22)	4.7 (.21)	4.3 (.34)	4.6
Resistance (too easy or too hard to push or turn)	4.8 (.27)	4.7 (.15)	4.6 (.22)	4.5 (.23)	4.7

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate = 2, very inadequate = 1.

*Rating was only required for overall conditions.

TABLE 10

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE OPERATING PROCEDURES FOR THE DRAGON NIGHT TRACKER (n = 10)

Procedure	Day	Day and smoke	Night	Night and smoke	Overall mean
Performing long-term surveillance (two or more continuous hours)	3.7 (.26)	3.9 (.28)	3.8 (.33)	3.9 (.31)	3.8
Storing the night tracker and case in the APC	4.5 (.22)	4.5 (.22)	4.3 (.26)	3.9 (.18)	4.3
Performing operator maintenance	4.8 (.13)	4.7 (.21)	4.2 (.29)	3.8 (.25)	4.4
Performing short-term surveillance (less than two continuous hours)	4.5 (.17)	4.6 (.16)	4.4 (.22)	4.1 (.18)	4.4
Storing the night tracker in the field handling case	4.7 (.15)	4.7 (.15)	4.5 (.22)	4.0 (.18)	4.5
Installing the night tracker on the launcher	4.9 (.10)	4.8 (.13)	4.4 (.22)	4.0 (.26)	4.5
Tracking a target with the night tracker	4.6 (.16)	4.7 (.15)	4.7 (.15)	4.4 (.16)	4.6
Removing the night tracker from the launcher	4.8 (.13)	4.8 (.13)	4.6 (.15)	4.3 (.30)	4.6
Connecting the night tracker to the vehicle power conditioner	4.9 (.11)	4.9 (.11)	4.8 (.15)	4.4 (.18)	4.8
Replacing batteries	4.9 (.10)	4.9 (.10)	4.7 (.15)	4.6 (.16)	4.8
Replacing coolant bottles	4.9 (.11)	4.9 (.11)	4.8 (.15)	4.7 (.17)	4.8

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate = 2, very inadequate = 1.

TABLE 11

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE SEVERITY OF PSYCHOLOGICAL AND/OR PHYSIOLOGICAL SYMPTOMS EXPERIENCED WHILE OPERATING THE DRAGON NIGHT TRACKER (n = 10)

Symptom	Day	Day and smoke	Night	Night and smoke	Overall mean
Difficulty focusing eyes	.8 (.20)	.9 (.23)	.8 (.25)	.8 (.33)	.8
Blurred vision after looking through device	.7 (.34)	.7 (.34)	.7 (.34)	.6 (.34)	.7
Drowsiness	.6 (.34)	.6 (.34)	.8 (.36)	.6 (.34)	.6
Blurred vision while looking through device	.6 (.31)	.6 (.31)	.5 (.31)	.4 (.31)	.5
Eyestrain	.5 (.17)	.7 (.26)	.2 (.13)	.5 (.27)	.5
Burning eyes	.6 (.27)	.6 (.34)	.3 (.21)	.4 (.31)	.5
Headache	.5 (.22)	.5 (.31)	.3 (.21)	.4 (.31)	.4
Tearing of eyes	.5 (.31)	.4 (.31)	.3 (.10)	.4 (.10)	.4
Muscle strain	.3 (.15)	.4 (.22)	.2 (.13)	.5 (.27)	.4
Nausea	.2 (.13)	.2 (.20)	.1 (.10)	.2 (.20)	.2
Dizziness	.2 (.13)	.2 (.20)	.1 (.10)	.2 (.20)	.2

NOTE: Did not experience = 0, mildly severe = 1, moderately severe = 2, extremely severe = 3.

Seven of ten operators that were interviewed stated that they experienced visual aftereffects after looking through the night tracker for 20 or 30 minutes. Five of the operators indicated that this was in the form of blurriness of vision and difficulty in focusing, but went away within a few minutes after their ceasing to look through the device. One operator said that he experienced some eyestrain after using the device for 20 or 25 minutes, and another operator who wore glasses said that he once experienced eyestrain within two or three minutes after beginning to look through the tracker.

Although the above findings reveal mild visual problems when using the device, particularly in the form of blurring of vision after using the device for 20 or 30 minutes, the operators did not consider these problems to be severe since they disappeared quite rapidly after the operators ceased looking through the devices.

In addition to visual problems, five of the operators indicated that they experienced muscle strain while operating the night tracker. Three complained of experiencing strain in the neck and back muscles after looking through the device for a prolonged period of time. The other two operators complained of leg muscle cramps and soreness. However, these problems did not preclude operators from adequately using the night tracker.

Three operators reported that they had experienced headaches while using the device. They all reported that they experienced this when they were tired or were operating in smoke. One of the operators said that he only experienced one headache and that occurred when he was standing about 30 feet down wind from a running smoke generator without his protective mask on. It thus appears that, in the latter case at least, this problem was caused by the test conditions (e.g. smoke, fatigue) rather than the night tracker itself.

Finally, two operators reported during the interviews that they experienced drowsiness while operating the night tracker. However, they felt that this was primarily due to boredom and the fact that it was at night, both factors of which are conducive to causing a state of drowsiness.

With respect to ratings of the severity of safety hazards experienced while operating the Dragon Night Tracker, only the category of extreme loudness received a rating other than "did not experience". The overall average rating of .1 for this category resulted from "mildly severe" ratings by one operator. This operator indicated during his interview that he gave that rating because he noticed that the night tracker made a "hissing noise" whenever he replaced a coolant bottle. However, he did not feel that this caused him any physical discomfort; rather, he felt that it was tactically unsound. Thus, it appears that there were no safety hazards encountered while operating the Dragon Night Tracker.

Night Observation Device - Long Range (NODLR)

The NODLR is illustrated in Figure 5. Overall mean ratings of the adequacy of the controls, shown in Table 12, ranged from 3.4 to 4.2, with most of the ratings falling within the "adequate" (3.5 to 4.5) range. Only two control characteristics received overall mean ratings in the "borderline" area (2.5 to 3.5). These included spacing between the controls (when working with gloves) and the size of labels. These low average ratings were caused by "borderline" ratings for nighttime conditions. Ratings of the location of labels and the visibility of controls also received average "borderline" ratings under night time conditions.

In the interviews, one of the operators stated that it was difficult to adjust the brightness and control knobs while wearing gloves because the knobs are positioned very close together.

Thus, while the findings from the rating scales indicated that there was a mild problem with the spacing between controls when working with gloves, the interviews revealed that this problem was primarily concerned with the spacing between the brightness and contrast knobs. This appears to be more of a problem at night than during the day because at night one depends more on touch than sight in determining where the controls are located. It was for this reason that "borderline" ratings were given to the visibility of controls at night. This would appear to be a minor problem, though, since, in the words of one operator: "While I couldn't read them all of the time, I memorized them."

Overall mean ratings of the adequacy of the operating procedures for the NODLR, shown in Table 13, ranged from 3.6 to 4.6. All of these ratings are in the "adequate" (3.5 to 4.5) or "very adequate" (4.5 to 5.0) range. The interviews, however, uncovered a number of problems in operating the NODLR. Several of these problems were similar to those encountered with the TOW Night Sight and the Dragon Night Tracker.

For instance, four of the five operators who were interviewed stated that there was somewhat of a problem in using the NODLR while wearing the M17 series protective mask in that one could not press his forehead against the lever in the eyepiece assembly in order to open the shutter and expose the field of view (one operator who used the M25 series protective mask said that this problem did not exist with that mask). This problem was solved by using the fingers to press on the shutter lever and hold the shutter open while viewing through the device. This was somewhat cumbersome in that it left just one hand available for adjusting the controls of the device and is a problem which would seem to merit further study and an eventual design solution.

One of the operators stated during the interviews that one difficulty that occurred in using the NODLR in the rain was that rain drops would accumulate on the front of the lens and thus reduce the effectiveness of the device. He suggested that a cowl be designed to extend from the front of the sight in order to protect the lens from rain.

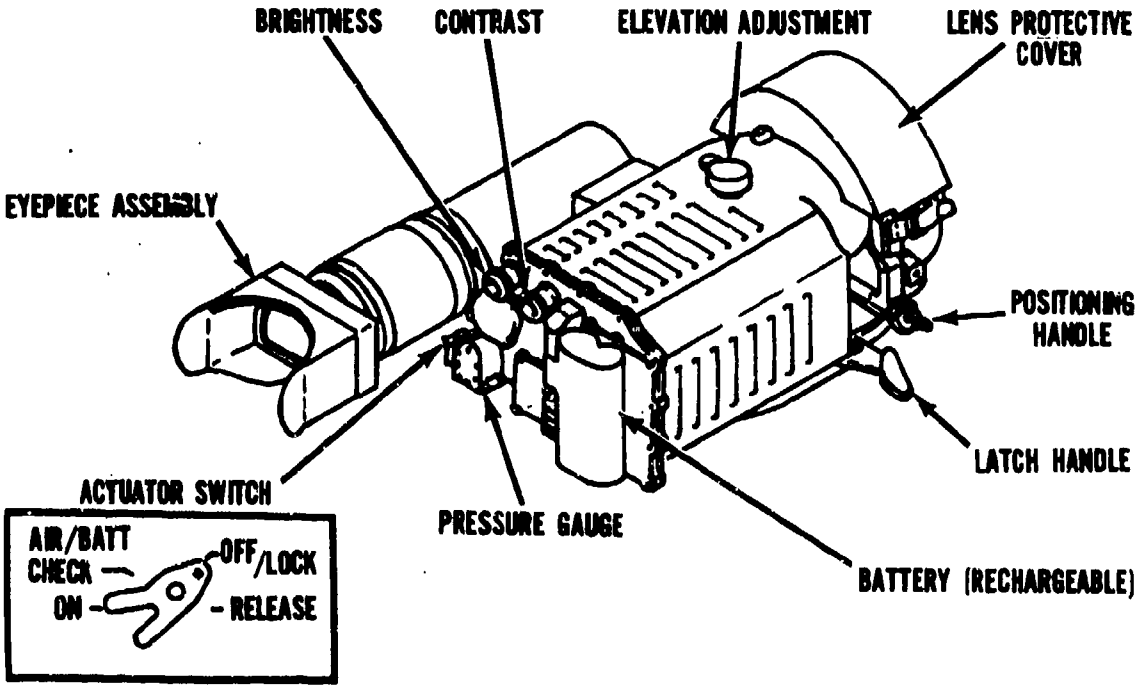

Figure 5. Night Observation Device, Long Range.

TABLE 12

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE CONTROLS OF THE NODLR (n = 5)

Control characteristics	Day	Day and smoke	Night	Night and smoke	Overall mean
Spacing between controls (with gloves)	3.6 (.60)	3.6 (.60)	3.2 (.80)	3.2 (.80)	3.4
Size of labels	4.0 (.45)	3.8 (.37)	3.0 (.55)	2.8 (.66)	3.4
Location of labels	4.0 (.45)	3.8 (.49)	3.2 (.49)	3.2 (.49)	3.6
Visibility of controls	4.0 (.45)	3.6 (.40)	3.4 (.51)	3.2 (.66)	3.6
Shape (with gloves	4.0 (.45)	4.0 (.45)	3.6 (.75)	3.6 (.75)	3.8
Reach distance of controls	3.8 (.75)	3.8 (.75)	3.8 (.75)	3.8 (.75)	3.8
Angle of view	4.0 (.45)	4.0 (.45)	3.8 (.58)	3.6 (.75)	3.8
Shape (without gloves	4.2 (.45)	3.8 (.45)	4.0 (.75)	3.6 (.75)	3.9
Location of controls	4.2 (.48)	3.8 (.75)	3.8 (.75)	3.8 (.75)	3.9
Size of controls (without gloves)	4.4 (.40)	4.0 (.45)	4.0 (.45)	3.6 (.75)	4.0
Size of controls (with gloves)	4.4 (.40)	4.2 (.37)	4.0 (.45)	3.4 (.75)	4.0
Absence of unrelated or confusing markings*					4.0
Spacing between controls (without gloves)	4.0 (.45)	4.2 (.37)	4.2 (.49)	4.2 (.49)	4.2
Resistance (too easy or too hard to push or turn)	4.2 (.48)	4.2 (.48)	4.2 (.48)	4.2 (.48)	4.2
Correct labels*					4.2
Understandable labels					4.2
Functional grouping (controls with related functions grouped together)	4.2 (.48)	4.2 (.48)	4.2 (.48)	4.2 (.48)	4.2

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate = 2, very inadequate = 1.

*Rating was only required for overall conditions.

TABLE 13

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE ADEQUACY OF THE OPERATING PROCEDURES FOR THE NODLR (n = 5)

Procedure	Day	Day and smoke	Night	Night and smoke	Overall mean
Performing operator maintenance	3.8 (.37)	3.6 (.40)	3.4 (.51)	3.4 (.51)	3.6
Performing long-term surveillance (two or more continuous hours)	3.6 (.60)	3.6 (.60)	3.8 (.58)	3.8 (.58)	3.7
Performing short-term surveillance (less than two continuous hours)	3.8 (.49)	3.8 (.49)	3.8 (.58)	3.8 (.58)	3.8
Installing the device on the tripod	3.8 (.58)	3.8 (.58)	3.8 (.74)	3.8 (.74)	3.8
Connecting the device on the vehicle power conditioner	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0 (.58)	4.0
Storing the device and case in the APC	4.0 (.78)	4.0 (.78)	4.0 (.78)	4.0 (.78)	4.0
Removing the device from the tripod	4.2 (.48)	4.2 (.48)	4.0 (.71)	4.0 (.71)	4.1
Replacing coolant bottles	4.2 (.49)	4.2 (.49)	4.4 (.40)	4.4 (.40	4.3
Storing the device in the field handling case	4.4 (.40)	4.4 (.40)	4.2 (.58)	4.2 (.58)	4.3
Replacing batteries	4.6 (.40)	4.6 (.40)	4.6 (.40)	4.6 (.40	4.6

NOTE: Very adequate = 5, adequate = 4, borderline = 3, inadequate = 2, very inadequate = 1.

Mean ratings of the severity of psychological and/or physiological symptoms which were experienced while operating the NODLR are shown in Table 14. The overall mean ratings extended from .7 (mildly severe") for eyestrain to 0 ("did not experience") for tearing of eyes, nausea, dizziness, and drowsiness.

In the interviews, one of the operators stated that he experienced eye strain while using the NODLR but that this occurred during smoke conditions and he attributed the eye strain to the smoke rather than to the device itself. Two other operators stated that they experienced blurry vision primarily during the day, after looking through the NODLR for about 10 minutes, but that their vision was restored to normal after looking away from the sight for two to five minutes. Thus, these effects are not long lasting, although it appears that continuous viewing for longer than 10 minutes is a problem for some operators.

The one operator who indicated on the rating form that he experienced headaches stated in the interview that he experienced them only after wearing the protective mask in a smoke condition. Thus, they were probably not caused by using the NODLR but were rather an effect of the test conditions.

Finally, the one operator who experienced muscle strain stated in the interview that he could not adjust the NODLR to a height that was comfortable for him (this operator said that he was 6'4" tall). This problem could be easily solved by designing a tripod for the NODLR with a greater range of vertical adjustment than exists with the present tripod.

Finally, operators reported that they did not experience any safety hazards while operating the NODLR.

TABLE 14

MEAN RATINGS (WITH STANDARD ERRORS IN PARENTHESES) OF THE SEVERITY OF PSYCHOLOGICAL AND/OR PHYSIOLOGICAL SYMPTOMS EXPERIENCED WHILE OPERATING THE NODLR

Symptom	Day	Day and smoke	Night	Night and smoke	Overall mean
Eye strain	.8 (.37)	1.0 (.32)	.4 (.24)	.4 (.24)	.7
Difficulty focusing eyes	.8 (.37)	.8 (.37)	.4 (.24)	.4 (.24)	.6
Blurred vision after looking through device	.6 (.24)	.6 (.24)	.4 (.24)	.4 (.24)	.5
Blurred vision while looking through device	.4 (.24)	.4 (.24)	.2 (.21)	.2 (.21)	.3
Burning eyes	.2 (.20)	.2 (.20)	.2 (.20)	.2 (.20)	.2
Muscle strain	.2 (.20)	.2 (.20)	.2 (.20)	.2 (.20)	.2
Headache	0.0 (.00)	.2 (.20)	0.0 (.00)	.2 (.20)	.1
Tearing of eyes	0.0 (.00)	0.0 (.00)	0.0 (.00)	0.0 (.00)	0.0
Nausea	0.0 (.00)	0.0 (.00)	0.0 (.00)	0.0 (.00)	0.0
Dizziness	0.0 (.00)	0.0 (.00)	0.0 (.00)	0.0 (.00)	0.0
Drowsiness	0.0 (.00)	0.0 (.00)	0.0 (.00)	0.0 (.00)	

NOTE: Did not experience = 0, mildly severe = 1, moderately severe = 2, extremely severe = 3.

CONCLUSIONS AND RECOMMENDATIONS

From a human factors perspective the PEWS appears to be quite adequate. However, a number of problems exist with the thermal imaging devices, the most serious of which involves the interface between the protective mask and both the TOW Night Sight and the Dragon Night Tracker. For instance, the M25 series protective mask, as currently designed, substantially interferes with an individual's ability to search for and track targets with both the TOW and Dragon weapon systems. All individuals who currently are in MOS positions where using the TOW gun is probable should be issued the M17 series protective mask. Most TOW gunners currently have that mask but TOW vehicle commanders, who are issued the M25 series mask, sometimes consider themselves the primary or alternate gunner and in such cases care should be taken to issue the M17 series mask to them since it is better than the M25 series mask for interfacing with the night sight.

Although the M17 series mask is preferable to the M25 series mask, designers of both the thermal imaging devices as well as designers of the next generation of protective masks should be made aware of the extensive reduction in the size of the sight picture when using the mask and the thermal imaging device together. At the same time, they should be informed of the severe problem involved in attempting to use corrective lens inserts with the protective mask while operating either the TOW Night Sight or the Dragon Night Tracker, as well as of the potential problem of breakage of the seal between the face and protective mask when exerting pressure against a resistent surface like the eyepiece assembly of the night sight. It should be noted, however, that primary responsibility for such problems lies with the party responsible for the development of the thermal imaging devices. Military Standard 1472B (Human Engineering Design Criteria for Military Systems, Equipment, and Facilities), Section 5.11.3.14.3, states: "Eyecups and headrests shall be compatible with helmets, protective masks, and other clothing and personal equipment." Thus, it is the responsibility of the designer of an eyepiece assembly to make it compatible with the protective mask, rather than vice versa. In this regard, those agencies responsible for the development of the thermal imaging devices should be informed of the present results so that the consideration of such problems can be incorporated into the planning and design of similar devices in the future.

Other equipment design changes which, it would appear, should receive serious consideration involve modifying TOW vehicles so that the gunner's platform can be adjusted approximately six inches upward to accomodate gunners of short stature, and designing a cowl to fit over the front lenses of the thermal imaging devices in order to keep raindrops from accumulating on them and reducing their effectiveness. Also, springloading the actuator switch on the thermal imaging devices so that there is increased kinesthetic feedback to the operator concerning the positions of the switch would reduce the problem associated with inadvertently rotating the switch too far and unintentionally releasing the coolant bottle from its coupling.

Finally, a number of problems could be solved by incorporating the following points into the training programs for operators of the thermal imaging devices:

1. Caution operators about the tendency on the part of inexperienced operators to accidently release the coolant bottle when merely attempting to shut the device off.

2. Caution the operators that although they might very well experience some visual aftereffects (for example, blurriness of vision, difficulty in focusing one's eyes) from looking through the sight for periods as short as 15 or 20 minutes, these effects are transitory and disappear within a few minutes after ceasing to look through the device.

3. Explain the effects of moisture getting on the device, being careful to point out that while a special cleansing solution, rather than water, needs to be used to clean the lens, this does not preclude using the devices in rain to search for and track targets.

APPENDIX

TOW NIGHT SIGHT (AN/TAS-4) HUMAN FACTORS QUESTIONNAIRE

NAME: _____

RANK: _____

UNIT: _____

DATE: _____

The purpose of the following questionnaire is to obtain your opinion of the TOW Night Sight and its accessories from an operator's point of view. Please answer each of the questions as accurately as you ca: based upon the experience you have had with the device. Any explanations or additional comments you would like to make will be recorded by the interviewer so that you do not have to spend your time writing them down. Please bear in mind that your answers are very important because they will be used to help make decisions concerning what information will be included in operations and training manuals for the TOW Night Sight. In all questions the term "device" is used to refer to the TOW Night Sight.

A. Using the scale to the right, indicate with a check mark (√) how adequate the controls and meters of the device are in each of the following areas. Response key as seen left to right: (5) very adequate, (4) adequate, (3) borderline, (2) inadequate, and (1) very inadequate.

	(5)	(4)	(3)	(2)	(1)
1. Size (without gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
2. Size (with gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
3. Shape (without gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
4. Shape (with gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
5. Spacing between controls (without gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
6. Spacing between controls (with gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
7. Resistance (too easy to turn or push or too hard to turn or push)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___

	(5)	(4)	(3)	(2)	(1)
8. Correct labels	___	___	___	___	___
9. Understandable labels.	___	___	___	___	___
10. Size of labels.					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
11. Location of labels.					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
12. Absence of unrelated or confusing markings.	___	___	___	___	___
13. Visibility of controls.					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
14. Angle of view.					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
15. Location of controls.					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
16. Reach distance of controls.					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___

		(5)	(4)	(3)	(2)	(1)
17.	Functional grouping (controls with related functions are grouped together)					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___
18.	Other (specify) _____					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___

B. Using the scale to the right, indicate with a check mark (✓) the adequacy of the controls of the TOW Night Sight boresight collimator. Response key as seen left to right: (5) very adequate, (4) adequate, (3) borderline, (2) inadequate, and (1) very inadequate.

	(5)	(4)	(3)	(2)	(1)
1. Size (without gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
2. Size (with gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
3. Shape (without gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
4. Shape (with gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
5. Spacing between controls (without gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
6. Spacing between controls (with gloves)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
7. Resistance (too easy to turn or push, or too hard to turn or push).					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___

		(5)	(4)	(3)	(2)	(1)
8.	Correct labels	___	___	___	___	___
9.	Understandable labels	___	___	___	___	___
10.	Size of labels					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___
11.	Location of labels.					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___
12.	Absence of unrelated or confusing markings	___	___	___	___	___
13.	Visibility of controls					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___
14.	Angle of view					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___
15.	Location of controls					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___
16.	Reach distance of controls					
	a. during daylight without smoke	___	___	___	___	___
	b. during daylight with smoke	___	___	___	___	___
	c. during night without smoke	___	___	___	___	___
	d. during night with smoke	___	___	___	___	___

	(5)	(4)	(3)	(2)	(1)
17. Functional grouping (controls with related functions are grouped together)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
18. Other (specify)_____					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___

C. Using the scale to the right, indicate with a check mark (✓) how easy or difficult it is to perform each of the following procedures. Response key from left to right: (5) very easy, (4) easy, (3) borderline, (2) difficult, and (1) very difficult.

	(5)	(4)	(3)	(2)	(1)
1. Installing the TOW Night Sight					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
2. Collimating the night sight					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
3. Replacing coolant bottles					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
4. Replacing batteries					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
5. Connecting the night sight to the vehicle power conditioner					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
6. Removing the night sight from the launcher					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
7. Storing the night sight in the field handling case					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___

	(5)	(4)	(3)	(2)	(1)
8. Storing the night sight and field handling case in the APC					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
9. Performing operator maintenance procedures					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
10. Tracking a target with the TOW night sight					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
11. Performing short term surveillance (less than 2 continuous hours) with the TOW night sight					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___
12. Performing long term surveillance (two or more continuous hours) with the TOW night sight)					
a. during daylight without smoke	___	___	___	___	___
b. during daylight with smoke	___	___	___	___	___
c. during night without smoke	___	___	___	___	___
d. during night with smoke	___	___	___	___	___

D. Indicate with a check mark (√) the severity of any of the following symptoms you experienced while viewing with the device. Response key as seen left to right: (0) did not experience, (1) mildly severe, (2) moderately severe, and (3) extremely severe.

	(0)	(1)	(2)	(3)	Estimate length of time of continuous operation before onset of symptom
1. Eyestrain.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
2. Burning eyes.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
3. Tearing of eyes.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
4. Difficulty focusing eyes.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
5. Blurred vision while looking through device.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
6. Blurred vision after looking through device.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____

	(0)	(1)	(2)	(3)	Estimate length of time of continuous operation before onset of symptom.
7. Headache.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
8. Nausea.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
9. Dizziness.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
10. Muscle strain.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
11. Drowsiness.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____
12. Other _____.					
a. during daylight without smoke	___	___	___	___	_____
b. during daylight with smoke	___	___	___	___	_____
c. during night without smoke	___	___	___	___	_____
d. during night with smoke	___	___	___	___	_____

E. Indicate with a check mark (✓) the severity of any safety hazards you have experienced while operating the device. Response key as seen left to right: (0) did not experience a hazard, (1) mildly severe, (2) moderately severe, and (3) extremely severe.

	(0)	(1)	(2)	(3)
1. Electrical shock				
a. during daylight without smoke	___	___	___	___
b. during daylight with smoke	___	___	___	___
c. during night without smoke	___	___	___	___
d. during night with smoke	___	___	___	___
2. Extreme heat or burns				
a. during daylight without smoke	___	___	___	___
b. during daylight with smoke	___	___	___	___
c. during night without smoke	___	___	___	___
d. during night with smoke	___	___	___	___
3. Cuts or abrasions				
a. during daylight without smoke	___	___	___	___
b. during daylight with smoke	___	___	___	___
c. during night without smoke	___	___	___	___
d. during night with smoke	___	___	___	___
4. Extreme brightness				
a. during daylight without smoke	___	___	___	___
b. during daylight with smoke	___	___	___	___
c. during night without smoke	___	___	___	___
d. during night with smoke	___	___	___	___
5. Extreme loudness				
a. during daylight without smoke	___	___	___	___
b. during daylight with smoke	___	___	___	___
c. during night without smoke	___	___	___	___
d. during night with smoke	___	___	___	___
6. Other (specify) _____				
a. during daylight without smoke	___	___	___	___
b. during daylight with smoke	___	___	___	___
c. during night without smoke	___	___	___	___
d. during night with smoke	___	___	___	___