Technical Memorandum 4-92

AN EVALUATION OF SEVERAL PERSONAL WEAPON-SIGHTING SYSTEMS DURING DAYTIME, DUSK, AND NIGHT AMBIENT LIGHT CONDITIONS

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U.S. ARMY HUMAN ENGINEERING LABORATORY

Aberdeen Proving Ground, Maryland

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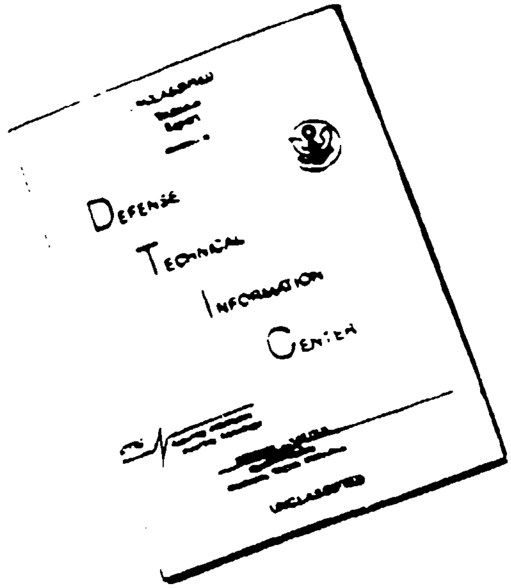

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The U.S. Army Human Engineering Laboratory (HEL) conducted a live fire performance of seven personal weapon-sighting systems. This study was a joint effort of the U.S. Border Patrol, the U.S. Army Combat Systems Test Activity (USACSTA), and the U.S. Army Center for Night Vision and Electro-optics (CNVEO). The weapon-sighting systems were mounted on Smith & Wesson 5900 series 9mm pistols. Standard iron sights were used as the baseline sighting system.

Twelve U.S. Border Patrol volunteers (eight male and four female) were used a subjects in this study. Three subtests were conducted in which all 12 subjects participated: day, low light (dusk), and night. For each subtest, the subjects fired at either single or double crouching man-type, E-silhouette targets from [illegible] to [illegible] meters, using varying target exposure times (1.5 to 5.0 seconds). For the day subtest, only three personal sighting systems were used: standard iron sights, tritium three-dot iron sights made by Trijicon, Inc., and a reflex collimating sight made by Aimpoint, Inc. For the dusk subtest, the same three sighting systems were used plus a visible laser-aided sighting system made by Lasermax, Inc. For the night subtest, all four sighting systems were used, along with AN/PVS7B night vision goggles (NVGs), which were used in conjunction with iron sights, a visible laser sight, and an infrared laser sight.

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Four measures of performance were collected from each subject-sighting-system condition during all three subtests: probability of a successful engagement (hits divided by target opportunities), time to hit, time to first shot, and number of shots fired.

The results indicated that for the day subtest, there were no significant differences between any of the sighting systems. For the dusk subtests, during double target engagement, the iron sights and tritium three-dot sights took significantly longer to fire the first shot than the visible laser sight did. During the night subtest, significantly more targets were hit with the visible laser-NVG and infrared-NVG sighting systems than with the iron-NVG, Aimpoint, iron sights, and tritium three-dot sights.

The overall conclusion was that there does not appear to be any reason to believe that any particular sighting system will out-perform any other until nighttime (the equivalent of full moon or darker) levels of ambient illumination prevail. During conditions of full moon or darker, a pistol equipped with either a visible or an infrared laser beam and used with the AN/PVS7B will significantly improve the probability of hitting a target.

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EXECUTIVE SUMMARY

In the latter part of December, 1990, the U.S. Army Combat Systems Test Activity (USACSTA), the U.S. Army Human Engineering Laboratory (HEL), the U.S. Border Patrol, the U.S. Immigration and Naturalization Service, and the U.S. Army Center for Night Vision and Electro-optics (CNVEO) put together an evaluation program of several pistol-aiming devices for use during daylight, dusk, and nighttime lighting conditions.

HEL wrote the evaluation plan and conducted the evaluation at a small arms range. The Border Patrol provided the test subjects, the pistols, and the ammunition, and CNVEO provided the AN/PVS7B night vision goggles (NVGs) and some of the sights and sight mounts. USACSTA provided for weapon and sight zeroing, maintenance, and storage.

The objective of this effort was to evaluate the performance of several types of pistol sights during a wide range of lighting conditions, and in some cases, in conjunction with AN/PVS7B night vision goggles. The results of this evaluation were to be used by the Border Patrol to judge the relative merits of various systems and to determine the best way to equip their field personnel for operations in daylight and during periods of reduced ambient light.

The methodology employed in evaluating these sighting systems was to conduct a series of live fire subtests with U.S. Border Patrol shooters during a wide range of ambient light conditions and against human type targets exposed for varying brief intervals of time. In addition to this, a debriefing was conducted at the end of the testing to solicit subjective opinions from the subjects about relative advantages and disadvantages of the sighting systems and how they might be used in the field.

The following sighting systems were evaluated:

- System A - standard iron sights (baseline)
- System B - standard iron sights with AN/PVS7B NVGs
- System C - tritium three-dot iron sights made by Trijicon, Inc.
- System D - visible laser beam made by Lasermax, Inc.
- System E - visible laser beam with AN/PVS7B NVGs
- System F - infrared laser beam (Lasermax, Inc.) with AN/PVS7B NVGs
- System G - reflex collimating sight made by Aimpoint, Inc.

The sighting systems were mounted on Smith & Wesson 5900 series semi-automatic pistols chambered for the 9x19mm NATO cartridge.

This evaluation was conducted as a series of three subtests, each to examine the effects that the sights have on shooter performance during specific conditions of ambient light.

Subtest 1 looked at shooter and sight performance during daylight. Subtest 2 addressed performance during conditions of dusk. Subtest 3 was conducted at night. Not all the sighting systems were evaluated in each of the subtests. Those that were used with night vision goggles were not tested during daylight or dusk. The test items for each subtest were

Subtest 1. The sights tested in subtest 1 (daylight) were

Iron sights

Tritium three-dot sights
Aimpoint

Subtest 2. The sighting systems tested in subtest 2 (dusk) were

Iron sights
Tritium three-dot sights
Visible laser
Aimpoint

Subtest 3. The sighting systems tested in subtest 3 (night) were

Iron sights
Iron sights with NVG
Tritium three-dot sights
Visible laser
Visible laser with NVG
Infrared laser with NVG
Aimpoint

Subtest 2 (Dusk) was broken into four segments. As the ambient light diminished each evening and reached each of four preselected values, target presentation scenarios were initiated for the subjects at the firing points. The four ambient light values used as presentation starting points were

Starting point	Footcandles
1	1.50
2	0.40
3	0.12
4	0.03

These starting points were spaced approximately 5-1/2 minutes apart on the curve that describes the decay of light at dusk. This spacing allowed ample time for each shooter to complete a firing scenario and covered the full range of the light gradient that constitutes dusk, down to the approximate equivalent of full moon.

Subtest 3 (night) conditions were considered to have been reached when the ambient light level read 0.012 footcandle (corresponding approximately to full moon) or darker. Ambient light was monitored continuously and recorded at the start and stop of each target scenario during subtests 2 and 3. At the beginning of this evaluation, the moon had just entered the first quarter and was nearly full by the last day.

The subjects were selected by the U.S. Border Patrol from a body of volunteers solicited from various regional Border Patrol offices and brought to Aberdeen Proving Ground. The criteria for the selection of subjects were that they be representative of the range of shooting training and skills within the Border Patrol population, have 20/20 visual acuity (uncorrected), and have normal color perception. It was also requested that a significant portion of the subjects be female. Hand dominance was not controlled for.

The Border Patrol provided 12 subjects for this evaluation (four women and eight men).

The evaluation was conducted at HEL's M range, which is an outdoor live fire small arms range. Each firing point has a microphone that senses the weapon muzzle noise upon firing and is used to initiate data recording for time to fire, hits, and so forth.

There was an electronic command and data link between the targets, the firing point, and a computer. The order and timing of the target arrays were pre-programmed.

The targets were stationary U.S. Army E type (crouching man) silhouettes mounted on pop-up mechanisms. They were painted with flat black paint to simulate the reflectivity of typical clothing that might be worn to avoid detection. The targets were hit sensitive so that they would go down when hit and transmit the time of hit to the data recording computer. The targets were all stationary.

A computer program was written to control the sequence and timing of target presentations. The program generated ten different target presentation scenarios to ensure that no shooter could memorize the sequence of target presentation variables (range, exposure time, azimuth, pairings, etc.). Each scenario included seven targets at 10, 25, and 50 meters. Three single targets and two pairs of targets were presented at each range. The single targets were exposed for 1.5, 3.0, and 5.0 seconds at each range, and the double targets were exposed for 3.0 and 5.0 seconds at each range. There was a 3-second between-target interval except for two longer delays embedded in each scenario to allow for weapon reloading. These occurred at points approximately one third and two thirds of the way through the scenarios, and lasted for 9 seconds.

A photometer was used to measure ambient light. The light sensor of the device was aimed at the open sky to take a diffuse reading over a wide area of the sky.

Subjects fired from the standing position using the two-handed firing technique as taught by the Border Patrol. The firing procedure was the same for each subtest. Each subject had three fully loaded (15 rounds) magazines at the firing point. The magazines were placed on the table where they could be easily reached during the target presentations. The subject was then given an unloaded test weapon and a loaded magazine. When the targets were about to be presented, the subjects at the firing points were instructed to load their weapons, assume the ready pistol position, and watch for targets. The subjects began shooting when the first target appeared. At two points during the scenario, the subjects were given time to reload the pistol.

Except for Subtest 2, a repeated measures test design was used so that each subject was exposed to each sighting system and condition of ambient light. While all the subjects participated in Subtest 2, each subject fired in only one of the four ambient light bands. Subject assignments to the four ambient light bands in Subtest 2 were random. However, some effort was made to evenly distribute subjects shooting skill in the four subgroups that fired in each light band.

Time to each shot, time to each hit, which rounds hit, and which targets were hit were collected. This was correlated with the shooter and condition data and target array and presentation data in the M range computer.

At the conclusion of the field portion of this evaluation, the subjects participated in a debriefing to solicit any opinions they might have regarding the sights tested, methods of employing them, and any other relevant topic.

A repeated measure analysis of variance (ANOVA) was performed for each type of target presentation (single and double). The results were checked for compound symmetry. If the assumption for compound symmetry was rejected, the conservative Greenhouse and Geiser adjustment for the degrees of freedom was performed. Scheffé's post hoc test was then used to determine the significant differences between means. Significance testing was at the 5% level.

The probability of a successful engagement was used as the primary measure of performance. Other performance measures chosen as possible discriminators between sights are time to fire, time to hit, number of shots fired.

RESULTS

Subtest 1; Daylight

When the data were combined over subject, trial, light level, range, and exposure time, there were no significant differences among sights in probability of a sucessful engagement (hits divided by target opportunities), time to hit, time to first shot, or number of shots fired.

Subtest 2; Dusk

Because of the test limitations, only three subjects could be allocated to each of the four light condition bands. As a result, a repeated measures ANOVA was conducted in which three subjects were considered nested in each of four light level conditions.

The data for the Dusk subtest when combined over subjects, trial, light level, range, and exposure time show that there are no significant differences among sights in terms of probability of a sucessful engagement, time to hit, or number of shots fired. For the double targets, it was determined that the iron and tritium three-dot sights took significantly more time to fire the first shot than the visible laser sight did.

Subtest 3; Night

A Scheffé's post hoc analysis for the single target data determined that significantly more targets were hit with the visible laser/NVG and IR/NVG systems than the iron/NVG, Aimpoint, iron and tritium three-dot sights. This was also true for the double target data. Additionally, the IR/NVG system hit significantly more targets in double target presentations than did the visible laser system.

When the data were collapsed over subject, trial, exposure time, and range, there were no significant differences among sights in terms of time to hit and time to first shot.

An analysis of the single target data showed that significantly more rounds were fired with the systems that used night vision goggles (iron/NVG, visible laser/NVG, and IR/NVG) than with the visible laser and tritium three-dot sights. Additionally, significantly more shots were fired with the iron/NVG system than with the iron and Aimpoint sights. The double target data show that significantly more shots were fired with the iron/NVG system than with any of the other sighting systems. Also, more shots were fired with the IR/NVG system than with the visible laser.

CONCLUSIONS

Subtest 1; Daylight

Subtest 1 revealed that there is no significant difference among iron, tritium three-dot, and Aimpoint sights in any of the measures that are considered to be important: probability of a successful engagement, time to fire, time to hit, and number of shots fired. Based on these data, there is no performance basis for selecting or rejecting one sight instead of any other for daytime use.

Subtest 2; Dusk

During the transient conditions of dusk, there were no significant differences among sights in terms of hits or time to hit. The visible laser sight was significantly faster (about 1/5 second) in mean time to fire than either the iron or the tritium three-dot sight against double targets. There were no significant differences among sights in number of shots fired.

Subtest 3; Night

At night, the probability of a successful engagement with either of the two laser beam-equipped weapons, when used with night vision goggles, was significantly higher (by a factor of two) than with the iron, iron with NVG, tritium three-dot, and Aimpoint sights against both single and double targets. Against double targets, the IR laser with NVG is also significantly better than the visible laser.

The data suggest that the visible laser nighttime hit performance may fall close to midway between that of the iron, iron with NVG, tritium three-dot, and Aimpoint sights, and the two laser beams when they are used with the night vision goggles.

Subtest 3 shows no sight to have an advantage or be at a disadvantage in terms of time to fire or time to hit at night.

Significant differences among sights were observed in terms of number of shots fired. The iron sight with NVG condition caused a significantly greater number of shots to be fired than the iron, tritium three-dot, visible laser, and Aimpoint sights against single targets, and all those plus the visible laser with NVG and IR laser with NVG sights against double targets. The other two night vision-aided conditions, IR and visible laser with NVG, exhibited significantly more shots fired than did the tritium three-dot and visible laser against single targets. The IR laser with NVG condition fired significantly more shots against double targets than did the visible laser without goggles. These data indicate that the mean number of shots fired at a target during these conditions with these weapons is simply a function of being able to see the targets. For this reason, it does not seem useful as a discriminator of sight performance.

When all the data from the three subtests are considered, there does not appear to be any reason to believe that any particular sight will out-perform any other sight until nighttime (the equivalent of full moon or darker) levels of ambient illumination prevail.

For daytime duty use, there seems to be little reason to carry a pistol with other than standard iron sights, especially when the cost and maintenance of the other sights and the requirement for batteries for several of them are considered.

During conditions of full moon or darker, a pistol equipped with either a visible or an infrared laser beam and used with the AN/PVS7B night vision goggles will significantly improve the probability of hitting a target. During those same conditions, a pistol equipped with a visible laser beam used without night vision goggles may provide a lesser, but material, improvement in hitting capability.

When there is a good chance that the duty pistol will also be used at night or during reduced levels of illumination during the day (as inside unlit buildings), a case might be made for carrying a pistol that has both standard iron sights and a compact visible laser beam projector. This would provide the shooter with some performance gain in comparison to iron sights in dim light without night vision goggles, and greatly improved performance with a familiar pistol when used with night vision goggles.

During the debriefing, the subjects indicated that they probably needed two systems: one to be carried constantly during duty hours and another for those occasions when a bulkier, heavier, more complicated system could be tolerated and would be more effective.

Based on the data produced in these evaluations, the weapon to be used during nighttime levels of illumination when bulk and complexity are less of an issue should be equipped with a laser beam and used in conjunction with night vision goggles. To the extent that greater bulk is tolerable, a rifle or shotgun might be a better choice than a pistol for tactical scenarios because of the greater range capability of these weapons. Another field evaluation should be conducted to investigate this possibility.

RECOMMENDATIONS

This evaluation uncovered no performance basis for recommending a particular pistol sight from among those tested, for people who must carry a semiautomatic pistol on their person as a regular course of duty (non-tactical use). This evaluation also did not find any justification for the added cost and complexity of any sight other than the standard iron sight as tested.

Visible laser beam projecting sights should be further investigated to see if one exists that adds no more bulk, performs at least as well, and is more rugged and reliable than the one evaluated in this report. If such a device is found, it should be field tested to determine its merit for tactical use.

For tactical use, a pistol equipped with a rugged and reliable laser beam projector (either visible or IR) and used in conjunction with night vision goggles is recommended.

An evaluation of other individual weapons such as rifles and shotguns, equipped with laser beam projectors and used with night vision goggles, should be conducted to see if such systems offer any advantages in comparison to pistols so equipped and employed.

AN EVALUATION OF SEVERAL PERSONAL WEAPON-SIGHTING SYSTEMS DURING DAYTIME, DUSK, AND NIGHT AMBIENT LIGHT CONDITIONS

INTRODUCTION

In the latter part of December, 1990, the U.S. Army Combat Systems Test Activity (USACSTA) contacted the U.S. Army Human Engineering Laboratory (HEL). USACSTA was involved in assisting the U.S. Border Patrol, the U.S. Immigration and Naturalization Service, and the U.S. Army Center for Night Vision and Electro-optics (CNVEO). These agencies put together an evaluation program of several pistol-aiming devices for use during daylight, dawn and dusk, and nighttime lighting conditions. Portions of the evaluation would be conducted using night vision goggles. The purpose of the call from USACSTA was to see if HEL would be interested in participating in this program, since the major issues are largely ones of human performance.

Because these types of aiming devices are of potential interest for use with infantry weapons, and few or no data are available that describe their effectiveness, HEL agreed to become involved in the testing. Consequently, a meeting was held on January 3, 1991, to discuss the scope of the program and to assign tasks to the various participants. The outcome of the meeting was that HEL would write the evaluation plan and conduct the evaluation itself at its M range using U.S. Border Patrol agents as subjects. The Border Patrol would provide the subjects, pistols, and ammunition, and CNVEO would provide the AN/PVS7B night vision goggles (NVGs) and some of the sights and sight mounts. USACSTA would provide for weapon and sight zeroing, maintenance, and storage.

OBJECTIVE

The objective of this effort was to evaluate the performance of several generic types of pistol sights during a wide range of lighting conditions, and in some cases, in conjunction with AN/PVS7B night vision goggles. The results of this evaluation were to be used by the Border Patrol to judge the relative merits of various systems and to determine the best way to equip their personnel for field operations in daylight and during periods of reduced ambient light.

METHODOLOGY

The methodology employed in evaluating these sighting systems was to conduct a series of live fire subtests with U.S. Border Patrol shooters during a wide range of ambient light conditions and against human type targets exposed for varying brief intervals of time. Performance data were collected and used for this purpose. In addition to this, a debriefing was conducted at the end of the testing to solicit subjects' opinions about relative advantages and disadvantages of the sighting systems, and how they might be used from a tactical standpoint (see Appendix A).

ITEMS EVALUATED

The following sighting systems were evaluated:

System A - standard iron sights (baseline)
System B - standard iron sights with AN/PVS7B night vision goggles
System C - tritium three-dot iron sights made by Trijicon, Inc.
System D - visible laser beam model MDL-200-670-10mW made by Lasermax, Inc.
System E - visible laser beam (as above) with AN/PVS7B night vision goggles
System F - infrared laser beam (same as above but with an infrared laser diode) with AN/PVS7B night vision goggles
System G - reflex collimating sight model Aimpoint 3000 made by Aimpoint, Inc.

Pistols

The sighting systems were mounted on three models of Smith & Wesson 5900 series semiautomatic pistols chambered for the 9x19mm NATO cartridge. These pistols were chosen by the Border Patrol because they closely follow the specifications for the service pistols that the Border Patrol intends to purchase and issue to all their agents in the near future. The reason that three different models were used is that Smith & Wesson had them available to lend to the Border Patrol at the time. These three models are actually variations of the same pistol. They have the same dimensions, grip stocks, trigger pull characteristics, barrel length, and so forth. They vary from each other in the area of decocking lever, safety lever, and hammer spur design. These features have nothing to do with the performance of the pistols as used in this sight evaluation.

The sights were attached to the pistols as specified in the sight manufacturer's instructions that came with the devices, or in the case of visible and infrared laser devices, by the manufacturer. The Border Patrol delivered the pistols for testing with the sights already mounted. The Border Patrol decided what type of sight would go on which model pistol. Once a given sight was mounted on a particular pistol, it remained on that pistol for the duration of the evaluation. Figures 1 through 7 show the pistols, sights, and night vision goggles.

The sight-pistol combinations were boresighted or zeroed from a Ransom Rest at the beginning of the testing and verified periodically throughout the evaluation. (Note. A Ransom Rest is a mechanical device the holds the pistol in a recoil-absorbing mount so that it can be aimed and fired with repeatable precision. The Ransom Rest was equipped with adjustment knobs for moving the pistol in azimuth and elevation for precise aiming.) Three of each type of sight mounted on dedicated pistols were available at the start of each day to ensure that malfunctions would not interrupt the scheduled shooting and to permit several subjects to fire the same condition at the same time.

The weapons and sights received daily inspection and cleaning before the day's shooting. Cleaning was done and repairs were made by the USACSTA Small Arms Repair Section where the weapons were secured when not involved in testing. USACSTA also rechecked the zero of the weapons on a regular basis.

Figure 1. System A - iron sights.

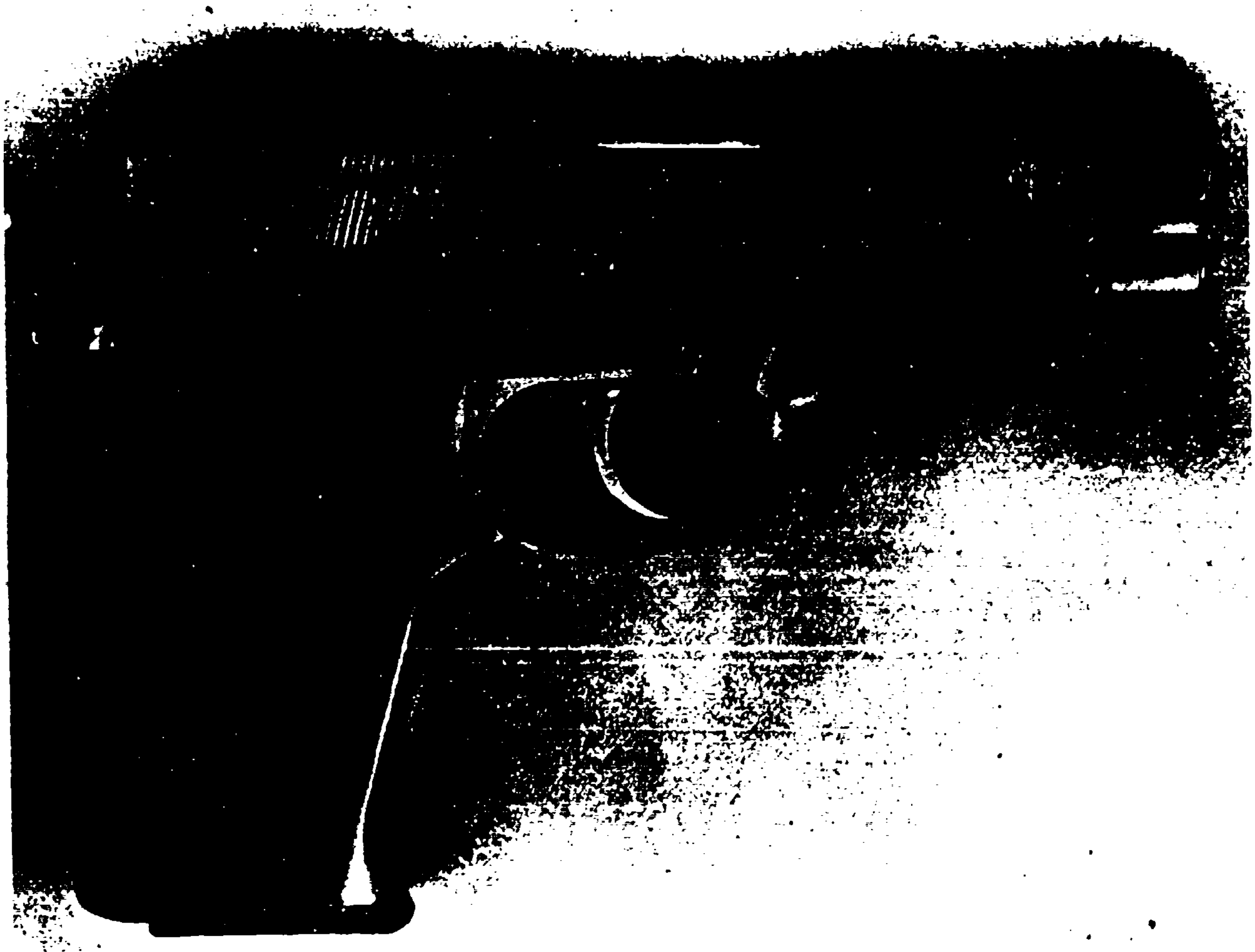


Figure 2. System C - tritium three-dot.

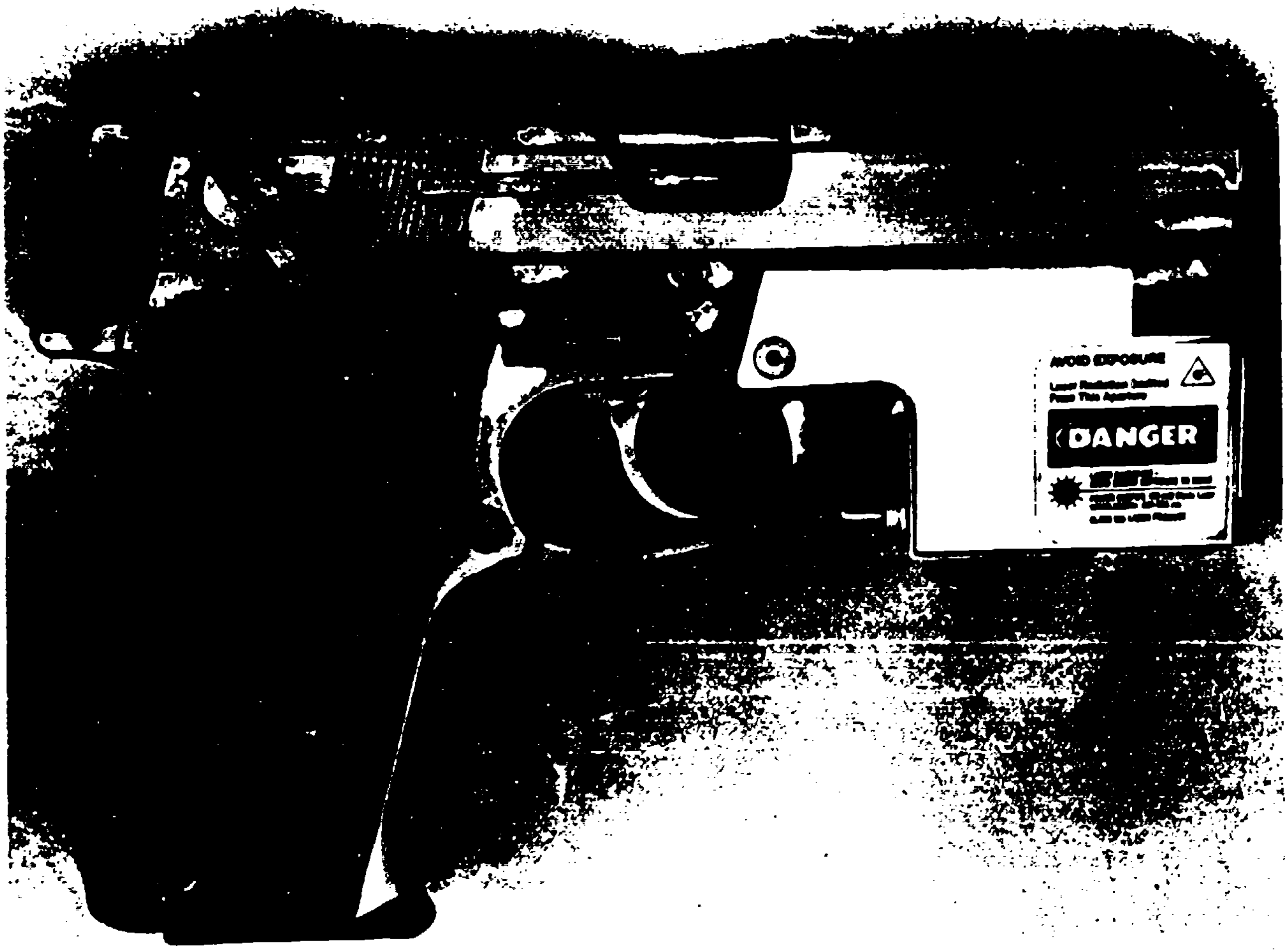


Figure 3. System D - visible laser.

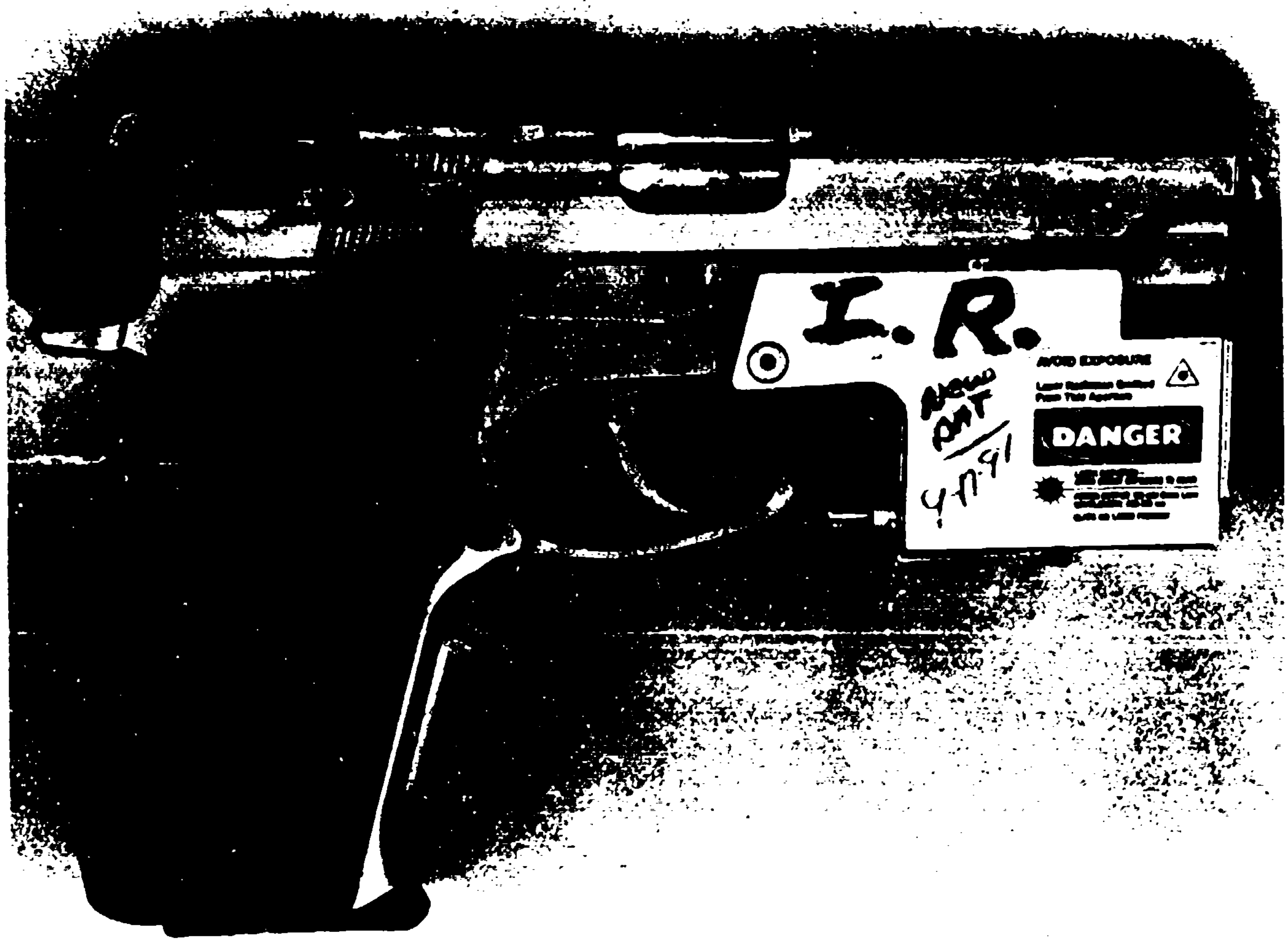


Figure 4. System F - infrared laser.

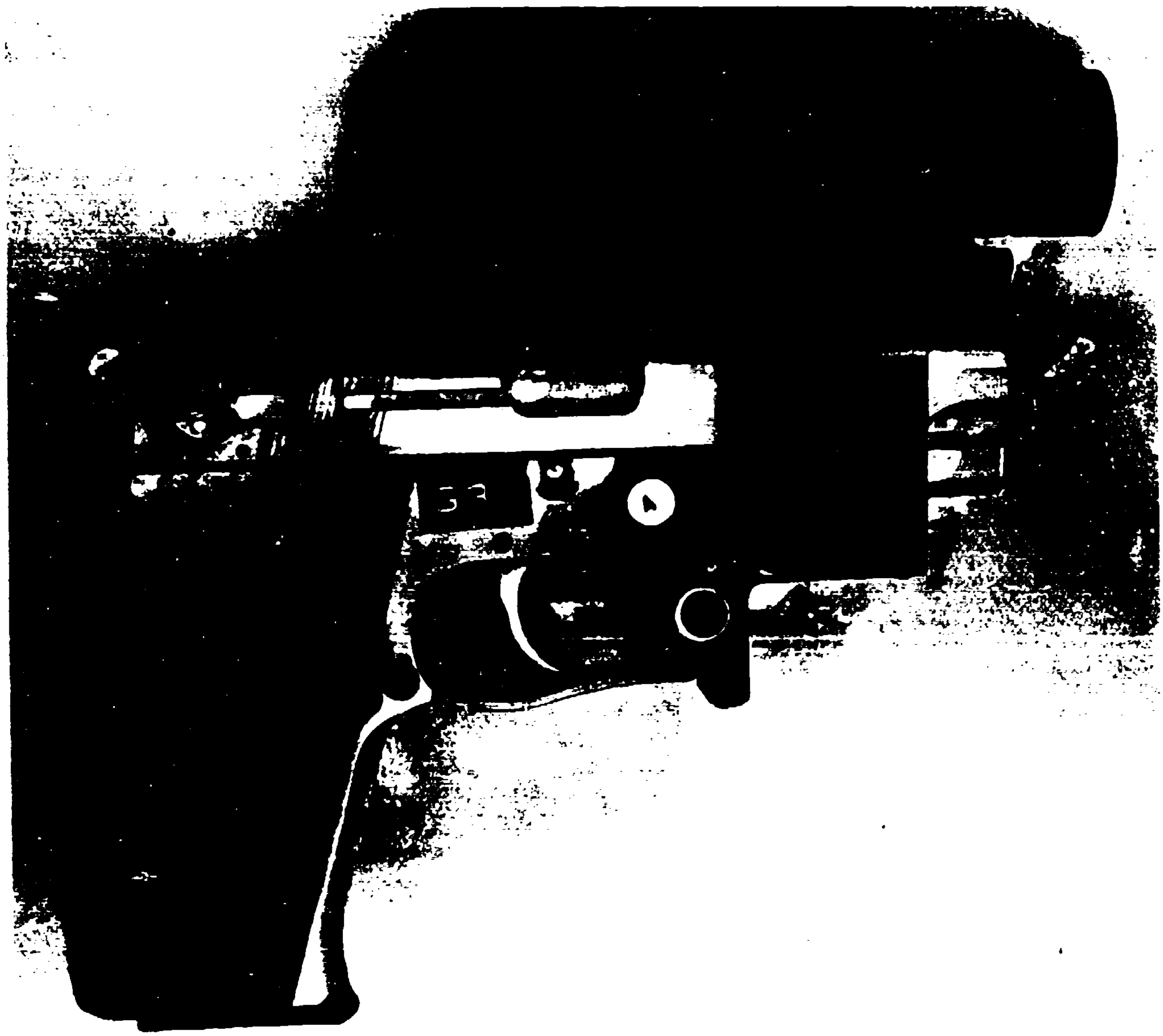
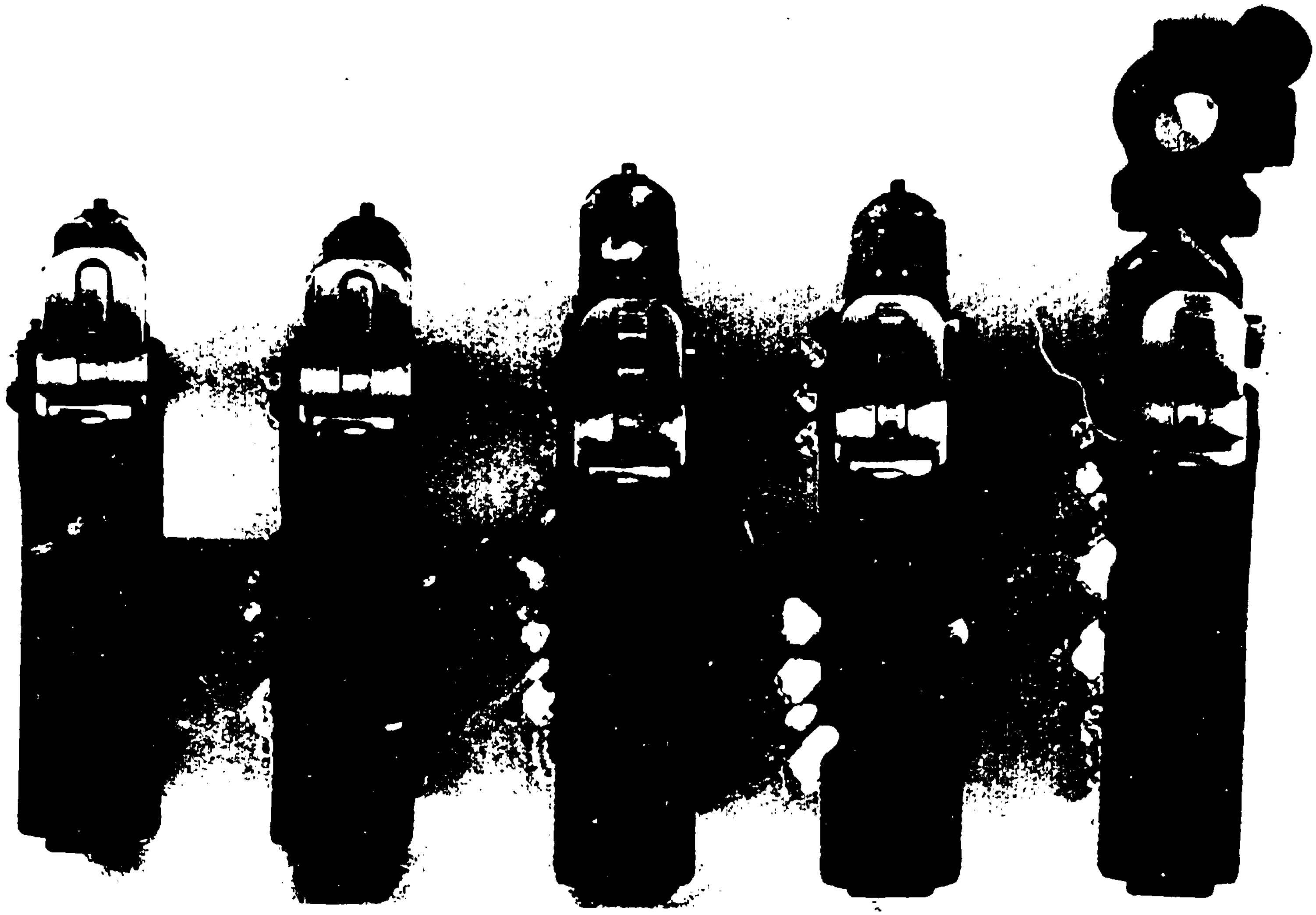


Figure 5. System G - aimpoint sight.



System A System C System D System F System G

Figure 6. The test weapons viewed from the rear.

Figure 7. AN/PVS7B night vision goggles.

Test Items

System A

Figure 1 shows System A, the baseline system. It was a Smith & Wesson Model 5926 with conventional iron sights. The pistol came from the manufacturer with three white dots painted into three shallow depressions machined into the back of the front and rear sight components. For this evaluation, these white dots were painted out so that the sights were like traditional iron pistol sights. This was done so that a three-dot system (System C) could be compared to plain iron sights during the daytime.

System B

System B was the same as system A except that it was used with AN/PVS7B night vision goggles. The AN/PVS7B night vision goggles are shown in Figure 7.

System C

System C, as shown in Figure 2, was exactly the same as System A (S & W Model 5926) except that Trijicon tritium gas-filled vials were installed where the white painted dots had been. Tritium is a luminescent radioactive isotope of hydrogen. The sight appears as a standard three-dot version of an iron sight during bright ambient illumination but glows during reduced light conditions.

System D

System D was a Smith & Wesson Model 5906 that had a Lasermax, Inc., MDL-200-670-10mW visible laser diode mounted on it at the Lasermax factory (see Figure 3). The laser diode is a Class IIIa battery-powered laser. The laser beam is turned on by a switch mounted directly in front of the pistol trigger guard. For this evaluation, the laser was turned on at the beginning of a target scenario and left on until the scenario was finished.

System E

System E was the same weapon as System D except that it was used in conjunction with the AN/PVS7B night vision goggles (see Figure 7). When viewed through the night vision goggles, the laser beam could be seen as an indistinct ghosted line ending in a bright ball when it struck the ground or an object.

System F

System F, as shown in Figure 4, was made by replacing the laser diode assembly in two spare System D weapons with infrared laser diodes also made by Lasermax. This system was operationally the same as System E, but when viewed through the night vision goggles, the laser beam appeared as a thin white line ending in a bright ball where it struck a target.

System G

System G is illustrated in Figure 5. The pistol was a Smith & Wesson Model 659. The sight was a unity power optical sight that had a battery-powered reticle that appeared as a red dot in the center of the rear lens. This sight was an Aimpoint 3000 manufactured by Aimpoint, Inc. It has a brightness control knob that allowed the shooter to vary the intensity of the reticle. The intensity of the dot was adjustable to suit the ambient light conditions. During daylight, the reticle was set at the brightest setting. At dusk, it was set three clicks dimmer, and at night, it was placed on the dimmest setting. Figure 6 shows all the pistol sights from the rear as the shooter would see them.

RESEARCH STRUCTURE

This research was planned and conducted as a series of three subtests, each to examine the effects that the sights have on shooter performance during specific conditions of ambient light.

Subtest 1 looked at shooter and sight performance during daylight. Subtest 2 addressed performance during conditions of dusk. Subtest 3 was conducted at night.

Not all the sighting systems were evaluated in each of the subtests. Those that were to be used with night vision goggles were not tested during daylight or dusk. The test items for each subtest were

Subtest 1; Daylight

- Iron sights
- Tritium three-dot sights
- Aimpoint

Subtest 2; Dusk

- Iron sights
- Tritium three-dot sights
- Visible laser
- Aimpoint

Subtest 3; Night

- Iron sights
- Iron sights with NVG
- Tritium three-dot sights
- Visible laser
- Visible laser with NVG
- Infrared (IR) laser with NVG
- Aimpoint

As an adjunct to these tests, on the last scheduled day of shooting, a cursory evaluation of four of the sights during conditions of headlight illumination at night was added to take advantage of an unused night that had been put in the schedule in case a makeup night was required for Subtest 3. These data are covered separately in Appendix B because time did not permit the evaluation to be conducted with the experimental controls that would give it a high degree of scientific validity.

AMBIENT LIGHT CONDITIONS

Subtest 1 was conducted in the early afternoon while it was still full daylight.

Subtest 2 was conducted at dusk. The ambient light was monitored continuously each evening starting before the onset of dusk (approximately 19:30 on 10 September) and continuing until the end of the evening's subtest program. As the ambient light diminished each evening and reached each of four preselected values, target-presentation scenarios were initiated for subjects waiting and ready at the firing points. The light level was recorded at the start and end of each target scenario. The four ambient light values used as presentation starting points are shown in Table 1.

Table 1

Ambient Light Values Used as Starting Points in Subtest 2

Starting point	Footcandles
1	1.50
2	0.40
3	0.12
4	0.03

Prior research (Ellis, Hanlon, & Ortega, 1989) about weapon sight performance during conditions of low ambient light and work done during contract to HEL (Kaprelian, 1988; Rogers, 1988) in support of that research, was most useful in determining these starting points.

These starting points were spaced approximately 5-1/2 minutes apart on the curve that describes the decay of light at dusk. Figure 8 shows these starting points superimposed on a plot of light decay as a function of time for a typical evening of the evaluation period. This spacing allowed ample time for each shooter to complete a firing scenario and covered the full range of the light gradient that constitutes dusk down to the approximate equivalent of full moon.

In Subtest 3, the sights were evaluated at night. Night conditions were considered to have been reached when the ambient light level read 0.012 footcandle (corresponding approximately to full moon) or darker. Ambient light was monitored continuously and recorded at the start and stop of each target scenario during Subtest 3 testing. At the beginning of this evaluation, the moon had just entered the first quarter and was nearly full by the last day.

SUBJECTS

The subjects were selected by the U.S. Border Patrol from a body of volunteers solicited from various regional Border Patrol offices and brought to Aberdeen Proving Ground. The criteria for the selection of subjects were that they be representative of the range of shooting training and skills within the Border Patrol population, have 20/20 visual acuity (uncorrected), and have normal color perception. The Border Patrol used recent medical records as a basis for the screening. It was also requested that a portion of the subjects be female. Hand dominance was not controlled for since it was not considered a relevant factor in an evaluation of pistol sights.

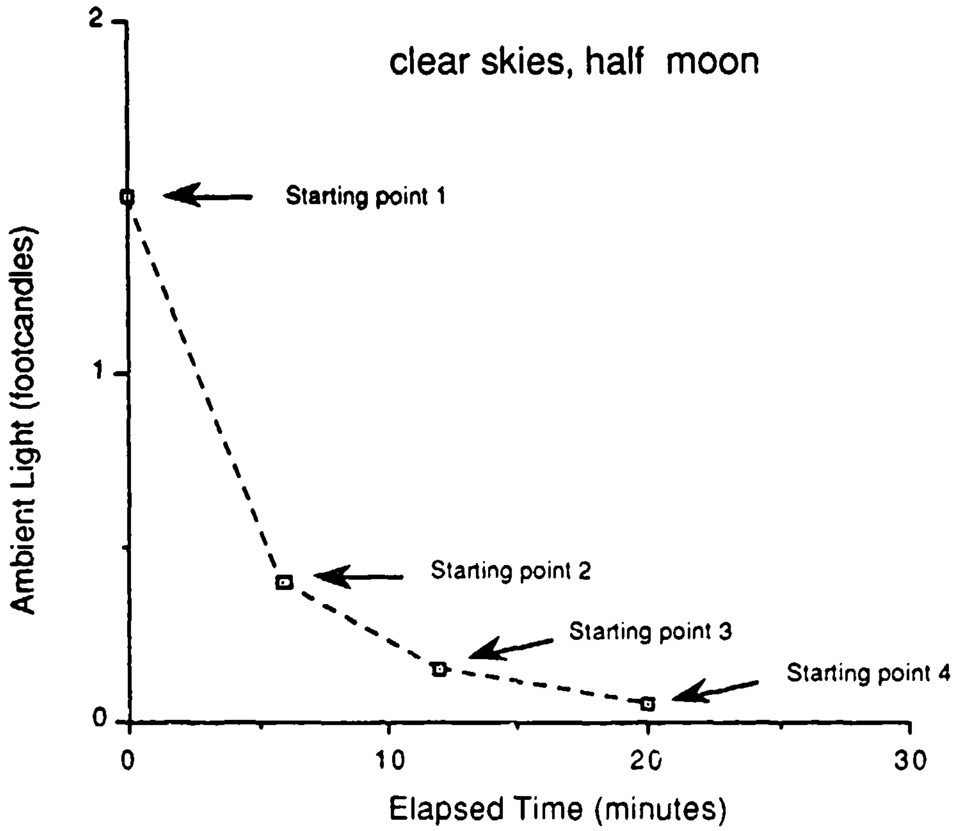


Figure 8. Typical ambient light decay at Aberdeen Proving Ground with clear skies and half moon in September 1991.

The Border Patrol was able to provide 12 subjects (eight men and four women) for ten working days for this evaluation. Nine subjects carried a revolver during the normal course of duty; the rest carried semiautomatics. Upon their arrival, it was discovered that one subject normally wore eyeglasses. It was decided that he would be included in the evaluation since the experimental design required 12 shooters, and it was too late to get a replacement.

TEST FACILITIES

M Range

The evaluation was conducted at HEL's M range, which is an outdoor live fire small arms range. Three firing points were used simultaneously for this evaluation; a fourth was held in reserve for makeup shooting when a subject had not been able to complete a trial because of a weapon, pistol, or range malfunction.

Each firing point commands a view of an array of targets that extend in a 50-meter-wide lane to 550 meters. Each firing lane is the exact duplicate of the next.

Each firing point has a microphone that senses the weapon muzzle noise upon firing and is used to initiate data recording for time to fire, hits, and so forth.

The view that the shooter sees from the firing point is a flat grassy surface that extends to a tree line at about 600 meters. Each target, when not in the raised position, is protected by an earthen berm that is about 2 feet high and of varying widths. The sloped front of the berms that face the shooter reflects the ambient light differently than does the range proper. The grass is not usually uniform in color. The result of this topography is that the targets are embedded in a visually "noisy" background.

The targets are controlled from a central command tower by means of a computer. There is an electronic command and data link among the targets, the firing point, and the computer. The order and timing of the target arrays can be pre-programmed.

Targets

The targets were stationary U.S. Army E type (crouching man) silhouettes mounted on pop-up mechanisms. They were painted with flat black paint to simulate the reflectivity of typical clothing that might be worn to avoid detection. The facial area of the targets was painted a medium tan to assist in target acquisition. The targets were hit sensitive so that they would go down when hit and transmit the time of hit to the data recording computer. The targets were all stationary. All targets were mounted in such a way that the frontal plane of each was perpendicular to the bullet path from the firing point. This ensured that the presented area of each target was the same independent of the angular displacement of the target.

TARGET SCENARIO PROGRAM

A computer program was written to control the sequence and timing of target presentations. The program generated ten different target presentation scenarios to ensure that no shooter could memorize the sequence of target presentation variables (range, exposure time, azimuth, pairings, etc.). Each scenario included seven targets at 10, 25, and 50 meters. Three single targets and two pairs of targets were presented at each range. The single targets were exposed for 1.5, 3.0, and 5.0 seconds at each range, and the double targets were exposed for 3.0 and 5.0 seconds at each range. There was a 3-second between-target interval except for two longer (10 seconds each) delays embedded in each scenario to allow for weapon reloading. These occurred at points approximately one third and two thirds of the way through the scenarios and lasted for 9 seconds. Appendix C shows the target presentation scenarios.

APPARATUS

A calibrated Tektronix Model J16 digital photometer was used to measure ambient light levels. The light sensor of the device was aimed straight up at the open sky and had a translucent dome over it to take a diffuse reading over a wide area of the sky. Readings for Subtest 2 (dusk) were taken continuously throughout the test and recorded at the start and finish of each target scenario. Light readings for Subtest 3 (night) were also monitored continuously and recorded at the beginning and end of each scenario that was fired for record. Appendix D shows the light level data sheets for Subtests 2 and 3. The measurements were recorded in footcandles.

PROCEDURE

Training

On the first day of this evaluation program, the subjects were taken to M range and given an orientation briefing about the purpose of these tests and the nature of their participation in them. They were told the objectives and procedures of each subtest. They were also shown the test items and received an explanation of how best to safely and effectively use each item. They were instructed in the safety procedures for M range and given administrative information. The subjects were encouraged to ask questions regarding any aspect of this program. At the end of the briefing, the subjects were given a volunteer agreement affidavit to read and sign (see Appendix E).

After the orientation briefing, the subjects were given instructions about how to engage the targets. They were instructed that upon seeing a target, they were to fire quickly and accurately. They were told that their primary objective was to hit the target and the secondary objective was to hit it quickly since they would have no way of knowing how long the target would be available. In addition, they were told that the targets would go down when hit.

The subjects then received familiarization training in the use of the baseline weapon, and on the range and test procedures on the first day of test. Thereafter, each subject's training for the sight condition to be shot for record took place just before firing for record. This training consisted of tutoring the subjects in the operation and techniques of firing the particular sight about to be tested and then allowing the subjects to shoot through two complete target scenarios. The subjects then fired for record. To minimize fatigue during this process, the subjects rotated alternately through this three-target scenario with the other subjects scheduled to fire at the same firing point; usually, either three or four subjects were at the same firing point at the same time.

Because of the rapidly changing nature of the ambient light during Subtest 2 (dusk), there was no time to train the subjects immediately before they were to fire. Instead, training and practice for Subtest 2 took place after the Subtest 3 firing the night before. This training consisted of a familiarization briefing about the sight to be fired in Subtest 2 the next day, and two live fire training trials with target scenarios. This meant that Subtest 2 began on the second night of the program rather than the first. In some cases, a subject fired the same sight condition in Subtest 3 that s/he was scheduled to fire the next day in Subtest 2. When this happened, no additional training with that sight took place.

Firing Technique

Subjects fired from the standing position using the two-handed firing technique as taught by the Border Patrol. The subjects engaged the targets starting from the standing "ready pistol" position. The ready pistol position is the same as the actual firing position except that the shooter swings his or her arms downward somewhat. This allowed an unobstructed view of the target area while the shooter looked for the next target. When the target appeared, the shooter would swing the weapon up until the sights were aligned on the target, obtain the proper sight picture, and fire.

The technique used when engaging targets with the visible laser system was for the shooter to shine the beam on the ground immediately in front of the 10-meter berm until a target appeared. When a target appeared, the red dot on the ground was quickly moved to the target and the pistol fired. The beam itself was not visible, and the only cue to its location that the shooter received was when the beam struck an object such as the ground or a target. The night vision goggles made it possible to see the laser beam itself, which gave the shooters a stronger visual cue about the location of the beam with respect to the target. This was especially true of the IR laser, which had a more sharply defined beam with less "blooming" around it.

Firing Procedure

The firing procedure was the same for each subtest. Each subject arrived at the firing point with three fully loaded (15 rounds) magazines. The weapons had been placed on a small table at the firing point before the subjects' arrival. The magazines were placed on the table where they could be easily reached during the target presentations. The subject was given a short familiarization briefing about the operation of the test item that s/he was about to shoot. The subjects were then given an unloaded test weapon and a loaded magazine. When the target control center was ready to present the targets and when the appropriate light level had been reached, the subjects at the firing points were instructed to load their weapons, assume the ready pistol position, and watch for targets. The subjects began shooting when the first target appeared.

At a point a third of the way through the scenario, and again two thirds of the way, a silver target (reload signal) appeared on the far left at ten meters to signal that it was time for the subject to reload the pistol. This target was not engaged. At this point, the subject removed the magazine from the weapon and inserted another fully loaded one that was on the table to the shooter's left. Ample time was allocated for this procedure. After the last target of each scenario had dropped from sight, the subject unloaded and put the pistol back on the table in a safe condition.

EXPERIMENTAL DESIGN

Except for Subtest 2, a repeated measures test design was used to expose each subject to each sighting system and condition of ambient light. While all the subjects participated in Subtest 2, each subject fired in only one of the four ambient light bands. (Note. Because the subjects were only available for ten test days, Subtest 2 scheduling required that the 12 subjects be divided into four groups of three shooters each. If all subjects had fired all light levels, the test would have required 16 days to complete.)

Before subjects were assigned to a group, each individual's shooting skill was estimated based on Border Patrol individual qualification score records. This was done in an effort to have the groups evenly matched with respect to shooting skill. The four groups were then randomly assigned to a light band, as was each subject's order of firing and the sequence of sight to be fired.

The subject-condition counterbalancing sequences are shown on Tables 2, 3, and 4. Note that the subjects were exposed twice to each condition in Subtests 1 and 2.

DATA COLLECTION

Time to each shot, time to each hit, which rounds hit, and which targets were hit were collected. This was correlated with the shooter-condition data and target array and presentation data in the M range computer.

At the conclusion of the field portion of this evaluation, the subjects were assembled in a conference room and debriefed. The purpose of this debriefing was to solicit any opinions the subjects might have regarding the sights tested, methods of employing them, and any other relevant topic. After the purpose of the debriefing was discussed with the subjects, an unstructured session ensued in which subjects were first asked to list the advantages and disadvantages of each sight in turn, starting with the baseline iron sights. The person conducting the debriefing recorded these comments on a large briefing pad on a stand in front of the subjects. The entire debriefing session was videotaped.

STATISTICAL ANALYSIS

A repeated measures analysis of variance (ANOVA) was performed for each type of target presentation (single and double). The results were checked for compound symmetry. If the assumption for compound symmetry was rejected, the conservative Greenhouse and Geiser adjustment for the degrees of freedom was performed. Scheffé's post hoc test was then used to determine the significant differences between means. Significance testing was at the .05 level. The results of these tests for significance are presented in Appendix F.

RESULTS

The results and the discussion of the results will be presented for each subtest independently. Generally, only results that pertain to the performance of the sights are shown. Not shown are data that describe relationships that are well understood and are independent of the type of sight employed; for example, marksmanship performance tends to degrade significantly as target distance increases, or as the target exposure time decreases. This is evident in the Range x Exposure Time interactions throughout the data.

The probability of a successful engagement is used as the primary measure of shooter-weapon performance. This probability is derived by dividing the number of targets hit by the number of target opportunities.

Other performance measures chosen as possible discriminators among sights are time to fire, time to hit, and number of shots fired.

Table 2

Presentation Order, Subtest 1, Daylight

	Subject number											
	1	2	3	4	5	6	7	8	9	10	11	12
Trial	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G	Sight A C G
1	3 1 5	1 3 7	5 7 1	7 5 3	1 7 3	7 1 5	3 5 1	5 3 7	7 3 1	5 1 7	3 7 5	1 5 3
2	4 8 6	6 2 4	2 6 8	8 4 2	2 4 8	6 2 4	4 8 6	8 6 2	4 2 6	2 6 8	8 4 2	6 8 4

Sight A = Iron sights
C = Tritium three-dot
G = Aimpoint

Note. Numbers under sight = test day

Table 3

Presentation Order, Subtest 2, Low light

Light Level	Trial	Subject number 1 Sight A C D G	2 Sight A C D G	3 Sight A C D G	4 Sight A C D G	5 Sight A C D G	6 Sight A C D G	7 Sight A C D G	8 Sight A C D G	9 Sight A C D G	10 Sight A C D G	11 Sight A C D G	12 Sight A C D G
1	1	2 4 6 8	8 6 4 2	6 4 2 8									
	2	3 9 5 7	9 5 7 3	5 3 9 7									
2	1				6 8 4 2	8 6 2 4	4 2 8 6						
	2				9 7 3 5	7 5 9 3	7 5 3 9						
3	1							2 8 6 4	4 6 2 8	2 8 4 6			
	2							3 9 7 5	5 7 3 9	3 7 5 9			
4	1										4 2 8 6	8 4 6 2	6 2 8 4
	2										5 3 9 7	9 3 7 5	7 9 5 3

Sight A = Iron sights
C = Tritium three-dot
D = Visible laser
G = Aimpoint

<u>Note</u>. Numbers under sight · test day

Table 4

Presentation Order, Subtest 3, Night

	Subject number											
	1	2	3	4	5	6	7	8	9	10	11	12
	Sight	Sight	Sight	Sight	Sight	Sight	Sight	Sight	Sight	Sight	Sight	Sight
	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG
Night	1234567	7654321	4521736	5167243	3745612	6412375	2376154	4651327	1763245	3427516	2546731	5314672

Sight A = Iron sights
B = Iron sights with night vision goggles (NVG)
C = Tritium three-dot
D = Visible laser
E = Visible laser with NVG
F = Infrared with NVG
G = Aimpoint

Note. Numbers under sight = test night

Subtest 1; Daylight

Hit Performance

Table 5 shows the probability of a successful engagement (hits per target opportunities) combined over subjects, trial, range, and exposure time. There was a significant range and exposure time main effect, and three significant interactions involving range and target exposure time. There was also a three-way interaction of Sight x Trial x Exposure Time. The interaction was caused by the iron sights seemingly performing better than the Aimpoint sight against the 1.5-second target in Trial 1, and seemingly worse than Aimpoint for that exposure time in Trial 2. It is unknown why this should be the case. Overall, there were no significant differences among sights.

Table 5

Hit Performance (day)

	Single target		Double targets	
Sight	Mean	SD	Mean	SD
Iron sights	.75	.44	.72	.45
Tritium three-dot	.80	.40	.79	.41
Aimpoint	.76	.76	.75	.43

Time to Hit

Table 6 shows the mean and standard deviation for time to hit (in seconds) collapsed over subject, trial, range and exposure time. There are no significant differences among sights or any other main effects.

Table 6

Time to Hit (day)

	Single target		Double targets	
Sight	Mean	SD	Mean	SD
Iron sights	1.65	.82	1.99	1.05
Tritium three-dot	1.65	.90	1.91	1.07
Aimpoint	1.50	.60	1.88	1.05

Time to First Shot

The mean and standard deviation of the time to first shot collapsed over subject, trial, range and exposure time are shown (in seconds) in Table 7. Only those occasions when a shot was fired were used in the analysis. There are no significant differences among sights. There was a significant range effect and Trial x Range interaction. There was also a significant trial main effect for the double targets.

Table 7

Time to First Shot (day)

Sight	Single target		Double targets	
	Mean	SD	Mean	SD
Iron sights	1.41	.39	1.15	.35
Tritium three-dot	1.34	.39	1.06	.38
Aimpoint	1.40	.46	1.10	.53

Number of Shots Fired

The mean number of shots fired collapsed over subject, trial, range, and target exposure time is shown in Table 8. There were no significant differences among sights. There was a significant main effect for range and exposure time caused by the Aimpoint sight firing significantly fewer shots at the target exposed for 5 seconds than did the two other weapons. There is no explanation for this other than chance, since the Aimpoint sight is not significantly different than any of the other sights in any other category of performance. Four interactions were also determined. Range and/or target exposure time was in each interaction.

Table 8

Number of Shots (day)

Sight	Single target		Double targets	
	Mean	SD	Mean	SD
Iron sights	1.25	.53	1.16	1.26
Tritium three-dot	1.25	.63	1.15	1.22
Aimpoint	1.13	.42	1.08	1.16

Subtest 2; Dusk

Because of test limitations, only three subjects were in each of four light condition bands. As a result, a repeated measures ANOVA was conducted in which three subjects were considered nested in each of the four light level conditions.

Hit Performance

Table 9 shows the probability of a successful engagement (hits per target opportunity) combined over subject, trial, light level, range, and exposure time. An ANOVA performed on these data determined a significant difference between ranges and between exposure times for both single and double target presentations. There were no significant differences among sights.

Table 9

Hit Performance (dusk)

	Single target		Double targets	
Sight	Mean	SD	Mean	SD
Iron sights	.59	.49	.63	.49
Tritium three-dot	.68	.47	.66	.47
Visible laser	.66	.47	.66	.47
Aimpoint	.73	.44	.72	.45

Time to Hit

The mean and standard deviation of the time to hit (in seconds) collapsed over subject, trial, range, exposure time, and light level are presented in Table 10. A significant main effect for range for the single target presentations, and a significant main effect for exposure time for double targets were determined. There were no significant differences among sights.

Table 10

Time to Hit (dusk)

	Single target		Double targets	
Sight	Mean	SD	Mean	SD
Iron sights	1.86	.96	2.12	1.06
Tritium three-dot	1.80	.78	2.18	1.12
Visible laser	1.78	.97	1.79	1.05
Aimpoint	1.59	.61	1.92	.94

Time to First Shot

The mean and standard deviation of the time to first shot collapsed over subject, trial, range, light level, and exposure time are shown (in seconds) in Table 11. The ANOVA performed on these data determined a significant main effect for range and exposure time for single target presentations. For the double targets, there was a significant main effect for sight and range.

The post hoc analysis of these data determined that for the single target presentation, there were no significant differences among sights. For the double targets, it was determined that the iron and tritium three-dot sights took significantly more time to fire the first shot than did the visible laser sight.

Table 11

Time to First Shot (dusk)

Sight	Single target Mean	Single target SD	Double targets Mean	Double targets SD
Iron sights	1.70	.52	1.38	.46
Tritium three-dot	1.65	.45	1.40	.47
Visible laser	1.54	.56	1.14	.53
Aimpoint	1.56	.53	1.28	.57

Number of Shots Fired

Table 12 shows the mean and standard deviation for number of shots fired at each target collapsed over subject, trial, light level, range, and exposure time. An ANOVA performed on these data determined a significant main effect for single target range and exposure time. There was a significant main effect for exposure time for double target presentations. There was also a Range x Exposure Time interaction for the single and double target data. There were no significant differences among sights.

Table 12

Number of Shots (dusk)

Sight	Single target Mean	Single target SD	Double targets Mean	Double targets SD
Iron sights	1.31	.65	1.16	1.29
Tritium three-dot	1.16	.46	1.09	1.17
Visible laser	1.24	.65	1.12	1.21
Aimpoint	1.10	.45	1.07	1.17

Subtest 3; Night

Hit Performance

Table 13 shows the mean and standard deviation of the probability of a successful engagement (hits per target opportunity) combined over subject, trial, range, and exposure time for nighttime.

The ANOVA performed on the these data determined that the sight, range, and exposure time main effects were significant for both the single and double target presentations. There were also four significant interactions involving range and exposure time for both the single and double target data sets.

A Scheffé's post hoc analysis for the single target data determined that significantly more targets were hit with the visible laser/NVG and IR/NVG systems than with the iron/NVG, Aimpoint, iron, and tritium three-dot sights. This was also true for the double target data. Additionally, the IR/NVG system hit significantly more targets in double target presentations than did the visible laser system.

Table 13

Hit Performance (night)

Sight	Single target Mean	Single target SD	Double targets Mean	Double targets SD
Iron sights	.33	.47	.34	.48
Iron with NVG	.25	.44	.26	.44
Tritium three-dot	.33	.47	.33	.47
Visible laser	.46	.50	.42	.50
Visible laser with NVG	.60	.49	.63	.49
IR laser with NVG	.64	.48	.67	.47
Aimpoint	.31	.47	.39	.49

Time to Hit

The mean and standard deviation of time to hit (in seconds) are shown in the Table 14 collapsed over subject, trial, exposure time, and range. There were no significant differences among sights or any other main effects.

Table 14

Time to Hit (night)

Sight	Single target Mean	Single target SD	Double targets Mean	Double targets SD
Iron sights	2.06	.87	2.46	1.21
Iron sights with NVG	2.10	1.13	2.52	1.20
Tritium three-dot	1.89	.47	2.24	.86
Visible laser	2.20	1.08	2.15	1.04
Visible laser with NVG	1.77	.81	1.20	.92
IR laser with NVG	1.80	.85	2.18	1.15
Aimpoint	2.18	1.11	2.65	1.06

Time to First Shot

Time to first shot collapsed over subject, trial, range, and exposure time is shown (in seconds) in Table 15. The ANOVA determined that the only significant main effect was attributable to the range of the single targets. There were no significant differences among sights.

Table 15

Time to First Shot (night)

Sight	Single target Mean	Single target SD	Double targets Mean	Double targets SD
Iron sights	1.87	.64	1.73	.67
Iron sights with NVG	1.74	.51	1.39	.42
Tritium three-dot	2.12	.62	2.17	.90
Visible laser	2.02	.88	1.84	.88
Visible laser with NVG	1.62	.59	1.39	.53
IR laser with NVG	1.60	.56	1.37	.51
Aimpoint	1.94	.69	1.89	.60

Number of Shots Fired

The mean and standard deviation of number of shots fired appear in Table 16 collapsed over subject, trial, range, and exposure time.

An ANOVA test established that sight, range, and exposure time main effects were significant for the number of shots fired for both the single and double target presentations. There were six interactions, each of which included range and/or exposure time.

A Scheffé's post hoc analysis of the single target data showed that significantly more rounds were fired with the systems that used night vision goggles (iron/NVG, visible laser/NVG, and IR/NVG) than with the visible laser and tritium three-dot sights. Additionally, significantly more shots were fired with the iron/NVG system than with the iron and Aimpoint sights.

A similar analysis of the double target data shows that significantly more shots were fired with the iron/NVG system than with any of the other sighting systems. Also, more shots were fired with the IR/NVG system than with the visible laser.

Table 16

Number of Shots (night)

Sight	Single target Mean	Single target SD	Double targets Mean	Double targets SD
Iron sights	1.08	1.01	1.00	1.53
Iron with NVG	1.69	1.11	1.55	1.81
Tritium three-dot	.77	.69	.78	1.12
Visible laser	.74	.63	.75	.99
Visible laser with NVG	1.24	.71	1.08	1.19
IR laser with NVG	1.30	.69	1.12	1.25
Aimpoint	.89	.86	.85	1.23

DEBRIEFING RESULTS

During the debriefing, the subjects were asked which sight they would prefer for each of two modes of service use; carrying from day to day for extended periods of time was the first mode addressed, and tactical use was the second. Tactical use was defined as those times when specialized equipment could be brought to a situation in a vehicle and used when longer term comfort or practicality was not as important. The subjects were asked to choose their first, second, and third preference for day, dusk, and night use. The responses are shown in Tables 17 and 18.

Table 17

Subject Preference, Duty Carry

For duty carry		First choice	Second choice	Third choice
DAYTIME	iron sights	0	10	0
	tritium three-dot	11	0	0
	Aimpoint	0	1	0
DUSK	iron sights	0	10	0
	tritium three-dot	11	0	0
	visible laser	0	0	0
	Aimpoint	0	1	0
NIGHT	iron sights	0	10	1
	iron sights with NVG	0	0	0
	tritium three-dot	10	1	0
	visible laser	1	0	9
	visible laser with NVG	0	0	0
	IR laser with NVG	0	0	0
	Aimpoint	0	0	0

Table 18

Subject Preference, Tactical Use

For tactical use		First choice	Second choice	Third choice
DAYTIME	iron sights	0	3	0
	tritium three-dot	6	5	0
	Aimpoint	5	3	0
DUSK	iron sights	[illegible]	[illegible]	0
	tritium three-dot	4	4	4
	visible laser	[illegible]	4	6
	Aimpoint	[illegible]	3	2
NIGHT	iron sights	[illegible]	[illegible]	0
	iron sights with NVG	[illegible]	[illegible]	0
	tritium three-dot	[illegible]	[illegible]	5
	visible laser	[illegible]	[illegible]	3
	visible laser with NVG	[illegible]	[illegible]	3
	IR laser with NVG	[illegible]	[illegible]	0
	Aimpoint	[illegible]	[illegible]	0

COMMENT: Some of the subjects felt that a good duty weapon would be a pistol that had both the tritium three-dot sights and the visible laser. They thought that the laser would not add to the bulk of the weapon to an objectionable degree, that the tritium sights would be used during daylight and sometimes at dusk, while the laser would be more effective during the darker part of dusk and at night. This concept, of course, was predicated on their opinion that the tritium out-performed the standard iron sights in daylight and at dusk (not supported by the data), and that the visible laser was better than iron sights during the conditions of dusk (data show that it may be faster in time to first shot), and the visible laser was better than the tritium sights at night (data suggest that it may achieve a higher probability of a sucessful engagement).

The subjects expressed concerns about the durability, reliability, and battery life of the sighting systems that were electronic. The Aimpoint sight could not be quickly removed so that the iron sights could be used if they failed. The laser beam systems did not interfere with the use of the iron sights, but the subjects seemed to be less confident in the reliability and durability of these devices than they were of the Aimpoint sight.

CONCLUSIONS

Subtest 1; Daylight

Subtest 1 revealed that there was no significant difference among iron, tritium three-dot, and Aimpoint sights in any of the measures that are considered to be important. Based on these data, there is no performance basis for selecting or rejecting one sight instead of any other for daytime use.

Subtest 2; Dusk

During the transient conditions of dusk, there were no significant differences among sights in terms of hits or time to hit.

The visible laser sight is significantly faster (about 1/4 second) in mean time to first shot than either the iron or the tritium three-dot sight against double targets. There were no significant differences among sights in number of shots fired.

Subtest 3; Night

At night, the probability of a successful engagement with either of the two laser beam-equipped weapons, when used with night vision goggles, is significantly higher than that of the iron, iron with NVG, tritium three-dot, and Aimpoint sights against both single and double targets. Against double targets, the IR laser with NVG is also significantly better than the visible laser.

The data suggest that the visible laser nighttime hit performance may fall close to midway between that of the iron, iron with NVG, tritium three-dot, and Aimpoint sights, and the two laser beams when they are used with the night vision goggles.

Subtest 3 shows no sight to have an advantage or be at a disadvantage in terms of time to fire or time to hit at night.

Significant differences among sights were observed in terms of number of shots fired. The iron sight with NVG condition caused a significantly greater number of shots to be fired than the iron, tritium three-dot, visible laser, and Aimpoint sights against single targets, and all those plus the visible laser with NVG and IR laser with NVG sights against double targets. The other two night vision-aided conditions, IR and visible laser with NVG, exhibited significantly more shots fired than the tritium three-dot and visible laser against single targets. The IR laser with NVG condition fired significantly more shots against double targets than the visible laser did without goggles. These data indicate that the mean number of shots fired at a target during these conditions, and with these weapons, is simply a function of being able to see the targets. For this reason, it does not seem useful as a discriminator of sight performance.

When all the data from the three subtests are considered, there does not appear to be any reason to believe that any particular sight will out-perform any other sight until nighttime (the equivalent of full moon or darker) levels of ambient illumination prevail.

For daytime duty use, there seems to be little reason to carry a pistol with other than standard iron sights, especially when the cost and maintenance of the other sights and the requirement for batteries for several of them are considered.

During conditions of full moon or darker, a pistol equipped with either a visible or an infrared laser beam, and used with the AN/PVS7B night vision goggles will significantly improve the probability of hitting a target. During those same conditions, a pistol equipped with a visible laser beam used without night vision goggles may provide a lesser, but material, improvement in hitting capability.

When there is a good chance that the duty pistol will also be used at night or during reduced levels of illumination during the day (as inside unlit buildings), a case might be made for carrying a pistol that has both standard iron sights and a compact visible laser beam projector. This would provide the shooter with some performance gain over iron sights in dim light without night vision goggles, and greatly improved performance with a familiar pistol when used with night vision goggles.

During the debriefing, the subjects indicated that they probably need two systems: one to be carried constantly during duty hours, and another for those occasions when a bulkier, heavier, more complicated system could be tolerated and would be more effective.

Based on the data produced in these evaluations, the weapon to be used during nighttime levels of illumination when bulk and complexity are less of an issue, should be equipped with a laser beam and used in conjunction with night vision goggles. To the extent that greater bulk is tolerable, a rifle or shotgun might be a better choice than a pistol for tactical scenarios because of the greater range capability of these weapons. Another field evaluation should be conducted to investigate this possibility.

RECOMMENDATIONS

This evaluation uncovered no performance basis for recommending a particular pistol sight from among those tested for people who must carry a semiautomatic pistol on their person as a regular course of duty (non-tactical use). In the same context, this evaluation did not find any justification for the added cost and complexity of any sight other than the standard iron sight as tested.

Visible laser beam projecting sights should be further investigated to see if one exists that adds no more bulk, performs at least as well, and is more rugged and reliable than the one evaluated in this report. If such a device is found, it should be field tested to determine its merit for tactical use.

For tactical use, a pistol equipped with a rugged and reliable laser beam projector (either visible or IR) and used in conjunction with night vision goggles is recommended.

An evaluation of other individual weapons such as rifles and shotguns equipped with laser beam projectors and used with night vision goggles should be conducted to see if such systems offer any advantages in comparison to pistols so equipped and employed.

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APPENDIX A

DEBRIEFING NOTES

DEBRIEFING NOTES

The following are the notes taken during the subject debriefing:

	ASSETS	LIABILITIES
IRON SIGHTS		
	Sturdy	Poor contrast with dark targets
	Compact	Can't see them at night
	Lightweight	Can't use with night vision goggles
	Training easy because of familiarity with sight	
	Minimal maintenance	
IRON SIGHTS WITH NVG		
	Can see the targets well with night vision goggles	Can't focus the goggles on sights so weapon must be pointed
TRITIUM THREE-DOT/IRON		
	Provides good contrast on all colors of target	Dots can be seen at night when pistol is holstered
	Cost effective for duty carry	Might need holster redesign to fix detection problem
	May assist in iron sight alignment	More difficult to zero sights
	Quick to align on target	May obscure target if too bright
	May work well with flashlight	
VISIBLE LASER		
	Excellent in combination with the tritium three-dot for use day and night	Can't use in daylight
	Visible beam could be a deterrent to adversary	Battery life a concern
	Easy to use. Walk beam into target	Doesn't work well with flashlight
	If you can see the target, you can hit it	Doesn't seem reliable or durable
	May be useful for analyzing training performance	Bulky
	Less weight than Aimpoint	Observable by adversary
	Gets better as light is reduced	Eye hazard to bystanders or other people
		Headlights wash out beam
VISIBLE LASER WITH NVG		
	Accurate	Halo around dot at 50 meters tended to obscure target
	Fast	Can't use in daylight
		AN/PVS7B uncomfortable
		Field of view is limited with AN/PVS7B
		Can be seen by adversary
		Requires batteries
		Goggles often fogged

ASSETS	LIABILITIES
IR LASER WITH NVG	
Can't be seen by adversary Fast target acquisition Excellent tactical weapon Could still use iron or three-dot sights without goggles in daylight	Halo tends to obscure 50-meter target Limited field of view from AN/PVS7B Seemed to require a warm-up period Durability a question Battery life a concern Depends on both goggles and laser working Potential eye hazard to bystanders or other patrolmen Goggles often fogged
AIMPOINT	
Good in daylight and dusk Fast in daylight and dusk, especially more distant targets Might be good with more training	Heavy, bulky Balance poor Interferes with immediate action to clear weapon malfunction. Better with revolver Not good in the dark unless target is silhouetted or in headlights Slower on the 10-meter targets Took longer to learn to use Dot brightness adjustment did not have wide enough range Requires time to turn device on Requires batteries No practical backup sights If the pistol is not aligned on the target, there is no cue as to where the dot can be found
AN/PVS7B NIGHT VISION GOGGLES	
Great night vision Harness seemed better than older type (AN/PVS5) Lighter weight than older type Didn't blank out as badly as the older type, recovered faster Had shorter warm-up time than older type	Bulky and uncomfortable Limited field of view Can't focus on sights and target at same time
SMITH AND WESSON 5900 SERIES PISTOLS	
Light recoil Fits small hands well Liked the single action trigger pull, compared to their Ruger revolvers	Single action trigger pull is heavy Malfunctions; double feeds and fails to eject Safety sometimes gets knocked on when the slide is racked (model 659) Decocking lever (model 5926) in way of slide lock

APPENDIX B

NIGHT VEHICLE HEADLIGHT TEST

NIGHT VEHICLE HEADLIGHT TEST

As an adjunct to the main evaluation subtests of this report, an evaluation of the performance of some of these sights during conditions simulating engaging targets illuminated by vehicle headlights at night was conducted on the last night available for shooting, after the main evaluation data had been collected.

The test fixture used to simulate a vehicle was a frame supporting two sets of high and low beam assemblies at the proper height, width, and relationship to replicate the driving lights (high beams) on a medium sized truck. The lights were powered by a set of batteries. The fixture was positioned slightly forward and to the right of the firing point, so that the shooter was approximately 4 feet to the left of the left headlight assembly and approximately 3 feet behind it.

The sights used were the same ones that had been tested in the Subtest 2: the iron, tritium three-dot, visible laser, and Aimpoint sights.

Each subject fired every sight. The subjects were randomly assigned a position in the firing order and fired a full target scenario twice.

Results

This test was conducted in the rain, and the headlight illumination had started to diminish because of weakened batteries before the test was concluded. These factors may have affected the results. For these reasons, the results are not considered to be sufficiently reliable for drawing definite conclusions. With the foregoing in mind, it should be noted that the data analysis indicated a significant difference ($<.05$) in only one instance; the probability of a sucessful engagement for the Aimpoint sight was significantly higher than that of the iron sights against single targets.

The results are shown in Tables B-1 through B-4.

Table B-1

Probability of a Sucessful Engagement

Sight	Single target Mean	Single target SD	Double targets Mean	Double targets SD
Iron sights	.56	.50	.61	.49
Tritium three-dot	.61	.49	.59	.49
Visible laser	.62	.49	.61	.49
Aimpoint	.78	.42	.70	.46

Table B-2

Time to Hit

Sight	Single target		Double targets	
	Mean	SD	Mean	SD
Iron sights	2.02	.89	2.30	1.16
Tritium three-dot	1.83	.74	2.25	1.10
Visible laser	1.88	.94	2.07	1.11
Aimpoint	1.93	.84	2.12	1.00

Table B-3

Time to First Shot

Sight	Single target		Double targets	
	Mean	SD	Mean	SD
Iron sights	1.77	.46	1.43	.42
Tritium three-dot	1.74	.45	1.42	.39
Visible laser	1.74	.63	1.43	.61
Aimpoint	1.67	.55	1.30	.47

Table B-4

Number of Shots

Sight	Single target		Double targets	
	Mean	SD	Mean	SD
Iron sights	1.40	.77	1.24	1.38
Tritium three-dot	1.21	.50	1.23	1.40
Visible laser	1.22	.65	1.10	1.22
Aimpoint	1.21	.64	1.17	1.27

APPENDIX C

TARGET PRESENTATION SCENARIOS

TARGET PRESENTATION SCENARIOS

EVENT:	1	2	3	4	5	MAG CHG	6	7	8	9	10	MAG CHG	11	12	13	14	15
TABLE 1:	25m-L	10m-R	50m-R	25m-LC	10m-LC		25m-C	10m-RC	50m-C	25m-R	10m-C		50m-LC	25m-RC	50m-L	10m-L	50m-RC
TIME:	5	3	3	5	3	6.5	3	5	1.5	1.5	5	6.5	3	3	5	1.5	5
TARGET NO.	7	4	13	7,8	2,3	1	8	3,4	12	9	3	1	11,12	8,9	[illegible]	2	12,13
TABLE 2:	50m-L	25m-R	10m-LC	10m-R	50m-RC		50m-C	10m-RC	25m-LC	50m-LC	10m-C		50m-R	25m-RC	25m-C	25m-L	10m-L
TIME:	3	5	5	1.5	3	6.5	5	3	3	5	3	6.5	1.5	5	1.5	3	5
TARGET NO.	11	9	2,3	4	12,13	1	12	3,4	7,8	11,12	3	1	13	8,9	8	7	2
TABLE 3:	25m-C	25m-R	50m-RC	10m-RC	25m-L		25m-RC	50m-L	10m-LC	50m-C	10m-R		25m-LC	10m-L	50m-R	50m-LC	10m-C
TIME:	1.5	3	5	5	5	6.5	3	1.5	3	3	1.5	6.5	5	5	5	3	3
TARGET NO.	8	9	12,13	3,4	7	1	8,9	11	2,3	12	4	1	7,8	2	13	11,12	3
TABLE 4:	10m-R	25m-LC	10m-C	10m-RC	50m-LC		25m-L	50m-RC	50m-L	10m-L	50m-R		25m-C	10m-LC	25m-R	50m-C	25m-RC
TIME:	3	3	1.5	5	5	6.5	5	3	5	5	1.5	6.5	3	3	1.5	3	5
TARGET NO.	4	7,8	3	3,4	11,12	1	7	12,13	11	2	13	1	8	2,3	9	12	8,9
TABLE 5:	10m-C	50m-RC	50m-L	25m-LC	10m-R		25m-R	25m-L	10m-LC	50m-C	10m-L		25m-RC	50m-LC	10m-RC	50m-R	25m-C
TIME:	1.5	5	1.5	3	3	6.5	5	3	3	3	5	6.5	5	3	5	5	1.5
TARGET NO.	3	12,13	11	7,8	4	1	9	7	2,3	12	2	1	9,9	11,12	3,4	13	8
TABLE 6:	25m-R	50m-RC	10m-R	25m-RC	50m-LC		10m-L	25m-LC	50m-L	50m-C	25m-C		10m-C	50m-R	10m-LC	25m-L	10m-RC
TIME:	5	5	1.5	3	3	6.5	3	[illegible]	3	1.5	3	6.5	5	5	5	1.5	3
TARGET NO.	9	12,13	4	9,9	11,12	[illegible]	2	7,8	11	12	8	[illegible]	3	13	2,3	7	3,4
TABLE 7:	50m-C	25m-RC	10m-R	10m-L	50m-RC		10m-LC	50m-R	10m-RC	25m-L	25m-LC		50m-L	25m-R	25m-C	10m-L	50m-LC
TIME:	5	3	3	1.5	5	6.5	5	1.5	3	5	5	6.5	3	3	1.5	5	3
TARGET NO.	12	8,9	4	5	12,13	1	2,3	13	3,4	7	7,8	1	11	9	8	2	11,12
TABLE 8:	[illegible]	50m-LC	10m-C	10m-R	25m-L		50m-RC	25m-C	50m-R	25m-R	50m-C		25m-RC	10m-LC	50m-L	10m-RC	25m-LC
TIME:	1.5	5	5	3	1.5	6.5	5	5	3	3	5	6.5	3	3	1.5	5	5
TARGET NO.	[illegible]	[illegible]	3	4	[illegible]	1	12,13	8	13	9	12	1	8,9	2,3	11	3,4	7,8
TABLE 9:	10m-R	25m-R	50m-LC	50m-R	10m-C		25m-C	50m-L	50m-RC	10m-RC	25m-RC		25m-L	10m-L	25m-LC	50m-C	10m-LC
TIME:	[illegible]	1.5	3	5	5	6.5	3	3	5	5	3	6.5	5	1.5	5	1.5	3
TARGET NO.	4	9	11,12	13	3	1	8	11	12,13	3,4	8,9	1	7	2	7,8	12	2,3
TABLE 10:	50m-R	10m-L	10m-C	50m-LC	25m-C		25m-RC	10m-R	50m-RC	10m-RC	25m-LC		50m-L	25m-R	10m-LC	25m-L	50m-C
TIME:	3	1.5	3	5	1.5	6.5	3	5	3	5	5	6.5	5	5	3	3	1.5
TARGET NO.	[illegible]	2	3	11,12	8	1	8,9	4	12,13	3,4	7,8	1	11	9	2,3	7	12

*** 3-SECOND DELAY BETWEEN EVENTS ***

APPENDIX D

LIGHT READING DATA

LIGHT READING DATA

AMBIENT CONDITIONS DURING FIRING

LOW LIGHT STUDY

Date	Start time	Light level	Stop time	Light level	Phase of Moon	Cloud Condition	Remarks
10SEP91	1937	1.500	1939	0.980	new moon, not showing	mostly cloudy	
	1944	.400	1946	.279			
	1951	.120	1953	.083		no stars showing	
	2000	.030	2003	.025			
11SEP91	1937	1.500	1939	.906		partly cloudy	
	1943	.400	1945	.248			
	1948	.120	1951	.0785			
	1956	.030	1958	.0228			
12SEP91	1937	1.500	1940	.840	¼ moon showing	partly overcast	
	1943	.400	1945	.257	moon behind MB range to right		
	1948	.120	1951	.0761			
	1951	.030	1958	.0212			
13SEP91	1931	1.500	1933	.938	¼ moon	mostly cloudy	moon not showing
	1937	.400	1939	.258		very cloudy	
	1942	.120	1944	.0811			
	1950	.030	1952	.0225			
16SEP91	1928	1.500	1930	.897	clear skies	½ moon showing	
	1934	.400	1936	.254			
	1939	.120	1942	.0795	½ moon showing		
	1948	.030	1950	.0251			
17SEP91	1919	1.4933	1921	.951	½ moon	very cloudy,	slight rain
	1927	.3933	1929	.265			
	1931	.1133	1933	.0664			
	1941	.0233	1943	.0204		dark clouds	lightning, lots of it.
18SEP91	1922	1.500	1924	.938	½ moon showing	Partly cloudy	ground fog, humid, forward of
	1928	.400	1930	.255		mostly cloudy	range
	1934	.120	1936	.075			moon covered by clouds, slight lightning
	1939	.030	1942	.0144			
19SEP91	1916	1.4933	1918	1.200	>½ not shown	clouds w/ lower	overcast, rain just finished
	1924	.3933	1926	.252			rain starting again
	1921	.1133	1933	.0854			
	1938	.0233	1940	.0134			
20SEP91	1924	1.500	1926	.434	¾ moon shown	partly cloudy	
	—	—	—	—			
	1936	.120	1938	.082			

Notes:

starting points:

LL 1 = 1.50 f-c
2 = .40
3 = .12
4 = .03

w/ Plastic cover on probe

1 = 1.4933
2 = .3433
3 = .1133
4 = .0233

AMBIENT CONDITIONS DURING FIRING

NIGHT SHOOT

Date	Start time	Light level	Stop time	Light level	Phase of Moon	Cloud Condition	Remarks
3SEP91	1750	1.500	1752	0.985	new moon	clear skies	
	1756	.400	1758	.258			
	2002	.128	2005	.0811			
	2011	.030	2010	.0246			
9SEP91	1959	.032	2001	.0245	new moon	partly cloudy	
	2003	.019	2006	.016		stars showing	no moon
	2007	.0148	2009	.0135	moon not showing		
	2011	.0127	2013	.0122			
	2017	.0116	2019	.0113			
	2021	.012	2023	.0110			
	2027	.0108	2029	.0107			
	2032	.0107	2035	.0106			
	2037	.0105	2039	.0105			
	2041	.0106	2043	.0105			
	2045	.0104	2048	.0104			
	2049	.0104	2051	.0104			
10SEP91	2026	.0131	2028	.0129			
	2030	.0128	2033	.0127		stars showing	
	2035	.0126	2037	.0126			
	2042	.0125	2044	.0124			
	2049	.0123	2052	.0122			
	2054	.0122	2056	.0121			
	2058	.0121	2101	.0120			
	2105	.0119	2105	.0119			
	2107	.0119	2109	.0119			
	2111	.0119	2113	.0119			
	2117	.0119	2.19	.0118			
	2121	.0118	2124	.0118			
	2128	.0117	2130	.0117			
	2132	.0117	2134	.0116			
	2136	.0117	2138	.0117			
11SEP91	2017	.0110	2019	.0110		very cloudy	no stars showing
	2020	.0110	2022	.0110	moon not showing		
	2027	.0110	2029	.0109			
	2031	.0109	2033	.0104		stars visible	
	2035	.0109	2038	.0108			
	2034	.0109	2041	.0104			
	2043	.0109	204[illegible]	.0108			
	2055	.0109	2058	.0109		clouds moving	
	2059	.0108	2101	[illegible]			
	2103	.0108	2105	.0108			

Notes:

AMBIENT CONDITIONS DURING FIRING

NIGHT SHOOT

Date	Start time	Light level	Stop time	Light level	Phase of Moon	Cloud Condition	Remarks
11SEP91	2107	0.0108	2109	.0108			
	2111	.0108	2113	.0108			
	2115	.0108	2117	.0108			
	2121	.0108	2123	.0108			
12SEP91	2011	.0074	2013	.0070	1/4 moon not showing	clear skies	
	2014	.0068	2017	.0066		stars showing	
	2019	.0064	2022	.0063			
	2023	.0062	2025	.0062			
	2026	.0060	2029	.0060			
	2030	.0060	2033	.0060			
	2034	.0058	2036	.0056			
	2038	.0057	2040	.0058			
	2042	.0058	2044	.0058			
	2046	.0058	2048	.0058			
	2053	.0058	2056	.0058			
	2057	.0058	2059	.0058			
	2102	.0057	2104	.0058			
	2107	.0057	2109	.0057			
	2111	.0057	2115	.0057			
13SEP91	2007	.0133	2011	.0132	1/4 moon not shown	clouds all over	no stars, no moon showing
	2013	.0131	2015	.0130			nothing showing
	2017	.0130	2019	.0130			
	2020	.0129	2022	.0129			
	2023	.0128	2025	.0127			
	2027	.0126	2029	.0126			
	2031	.0126	2035	.0126			
	2034	.0126	2036	.0126			
	2051	.0125	2053	.0125			
	2054	.0126	2056	.0126			
	2058	.0126	2100	.0126			
	2101	.0126	2103	.0126			
	2107	.0125	2109	.0125			
	2114	.0123	2116	.0123		clouds lessening	stars beginning to show
	2117	.0121	2120	.0114			
	2121	.0118	2123	.0117		clearing clouds	stars visible
16SEP91	2117	.0158	2119	.0158	1/2 moon showing		few stars showing
	2120	.0158	2122	.0154			
	2124	.0154	2126	.0159			
	2127	.0159	2129	.0160			
	2131	.0160	2134	.0160			
	2135	.0160	2137	.0160			

Notes:

AMBIENT CONDITIONS DURING FIRING

NIGHT SHOOT

Date	Start time	Light level	Stop time	Light level	Phase of Moon	Cloud Condition	Remarks
16SEP91	2139	.0159	41	.0160	½ moon showing	Partly cloudy	
	2142	.0160	2144	.0161			
	2146	.0161	2148	.0161			
	2149	.0161	2151	.0161			
	2153	.0161	2155	.0161			
	2157	.0161	2159	.0161			
	2207	.0159	2209	.0159			
	2211	.0159	2213	.0159			
	2214	.0159	2217	.0159			
	2218	.0159	2220	.0160			
	2221	.0160	2223	.0160		skies clearing	more stars visible
	2225	.0159	2227	.0159			
18SEP91	2005	.0034	2007	.0034	½ moon, covered by	clouds, lightning	from a distance, dark clouds over range.
	2008	.0034	2011	.0034			
	2014	.0033	2017	.0033			
	2018	.0039	2020	.0034			lightning about every 2 seconds!
	2021	.0034	2024	.0038			
	2025	.0037	2027	.0036			
	2028	.0035	2030	.0037			
	2031	.0038	2033	.0038			
	2035	.0038	2037	.0038			
	2055	.0034	2057	.0034			
	2059	.0034	2101	.0034			
	2102	.0034	2104	.0030			
	2109	.0026	2112	.0026		dark clouds covered moon	
	2113	.0026	2115	.0026			
	2117	.0026	2119	.0026			
			red flashing light on				
19SEP91	2003	.0023			½ not showing	clouds all over	dark type of clouds
							rain just stopped
							no stars showing
	2019	.0015	2021	.0015			
	2022	.0015	2024	.0015			
	2025	.0016	2027	.0014			removed plastic cover over probe
	2028	.0020	2030	.0019			

Notes:

APPENDIX E

VOLUNTEER AGREEMENT

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 70-25; the proponent agency is OTSG

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087.

Principle Purpose: To document voluntary participation in the Clinical Investigation and Research Program. SSN and home address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study; implementation of medical programs; adjudication of claims; and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A(1) - VOLUNTEER AFFIDAVIT

Volunteer Subjects in Approved Department of the Army Research Studies

Volunteers under the provisions of AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or disease which is the proximate result of their participation in such studies.

I, ______________________________, SSN ______________.

having full capacity to consent and having attained my ____________ birthday, do hereby volunteer/give consent as legal representative for ______________________________ to participate in An Evaluation of Several Personal Weapon Sighting Systems During Daytime, Dusk, and Night Ambient Light Conditions.

(Research study)

under the direction of Mr. Paul H. Ellis

conducted at The U.S. Army Human Engineering Laboratory M-Range Test Facility, APG, MD

(Name of Institution)

The implications of my voluntary participation/consent as legal representative; duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

Mr. Paul H. Ellis, (410) 278-5930

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights/the rights of the person I represent on study-related injury, I may contact

____

at Kirk U.S. Army Health Clinic, APG, MD (410) 278-4088.

(Name, Address and Phone Number of Hospital (Include Area Code))

I understand that I may at any time during the course of this study revoke my consent and withdraw/have the person I represent withdrawn from the study without further penalty or loss of benefits; however, I/the person I represent may be required (military volunteer) or requested (*civilian volunteer*) to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my/the person I represent's health and well-being. My/the person I represent's refusal to participate will involve no penalty or loss of benefits to which I am/the person I represent is otherwise entitled.

____

PART A (2) - ASSENT VOLUNTEER AFFIDAVIT *(MINOR CHILD)*

I, ______________________________, SSN ______________ having full capacity to consent and having attained my ____________ birthday, do hereby volunteer for ______________________________ to participate in ______________________________

(Research Study)

____

under the direction of ______________________________

conducted at ______________________________.

(Name of Institution)

(Continue on Reverse)

PART A(2) - ASSENT VOLUNTEER AFFIDAVIT (MINOR CHILD) (Cont'd.)

The implications of my voluntary participation; the nature, duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

____

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights I may contact

____

at ____

(Name, Address, and Phone Number of Hospital (Include Area Code))

I understand that I may at any time during the course of this study revoke my assent and withdraw from the study without further penalty or loss of benefits; however, I may be requested to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my health and well-being. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

____

PART B - TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: *(Provide a detailed explanation in accordance with Appendix E, AR 40-38 or AR 70-25.)*

You were presented a pretest briefing which verbally explained your involvement in this evaluation of several pistol aiming devices, that is being conducted to assist the U.S. Border Patrol in better equipping their agents. During the pretest briefing, range safety procedures and class III a laser safety precaution were explained to you. Afterwards, you were given the opportunity to ask questions relative to any aspect of your participation in this evaluation, and these were answered to your satisfaction before you volunteered to become a test participant.

To reiterate, this evaluation will require that you fire 9mm semi-automatic pistols equipped with several different aiming devices (i.: n sights, luminescent 3 dot, unity telescope w/red dot reticle, visible laser beam, and IR laser beam) sometimes in conjunction with AN/PVS night vision goggles. The evaluation will be conducted in the afternoon, at dusk, and after dark, and require your presence at the U.S. Army Human Engineering M-Range between the approximate hours of 1300 to 2200. The evaluation will start on 9 September and continue through 20 September 1991 exclusive of weekends.

You will be firing at pop-up silhouette targets at 10, 25, and 50 meters. The targets will be exposed for 1.5, 3.0, and 5.0 seconds. You will be trained in the proper method of using each sighting system and given practice in their use before firing for record. A typical firing sequence will be as follows:

At your assigned firing point you will be handed an unloaded weapon and a magazine with 15 rounds in it. You will be instructed on how to engage the targets, and when ready, will be given a 21 target scenario to shoot at. You will be given two opportunities to reload during each scenario. After you have been presented the last target you will be told to remove the magazine, clear the pistol, and put it in safe condition.

(CONT'D ON PAGE 3)

I do ☐ do not ☐ *(check one & initial)* consent to the inclusion of this form in my outpatient medical treatment record.

SIGNATURE OF VOLUNTEER	DATE	SIGNATURE OF LEGAL GUARDIAN *(If volunteer is a minor)*
PERMANENT ADDRESS OF VOLUNTEER	TYPED NAME OF WITNESS	
	SIGNATURE OF WITNESS	DATE

REVERSE OF DA FORM 5303-R, MAY 88

PART B OF THE VOLUNTEER CONSENT AGREEMENT (Cont'd)

An Evaluation of Several Personal Weapon Sighting Systems During Daytime, Dusk, and Night Ambient Light Conditions.

The conduct of the firing at M-Range will be in strict accordance with the established HEL standard safety operating procedures. Participation in this evaluation will be no more hazardous than your normal small arms practice sessions.

Your firing performance in this evaluation will be held in confidence, will not become part of your personal Border Patrol file, and will be released to no one. Your name will not appear in any report or other public disclosure of the test results.

APPENDIX F

STATISTICAL ANALYSIS

STATISTICAL ANALYSIS

Table F-1

Subtest 1. Analysis of Variance for Number of Targets Hit (single targets)

Source	SS	df	MS	F	p
TP	6.91	11	0.63		
sight	0.35	2	0.17	1.72	ns
(sight x tp)	2.21	22	0.10		
trial	0.12	1	0.12	1.03	ns
(trial x tp)	1.34	11	0.12		
range	29.67	2	14.83	83.99	<0.05 **
(range x tp)	3.89	22	0.18		
xtime	7.61	2	3.81	38.71	<0.05 **
(xtime x tp)	2.16	22	0.10		
sight x trial	0.33	2	0.17	1.41	ns
(sight x trial x tp)	2.59	22	0.12		
sight x range	0.24	4	0.06	0.61	ns
(sight x range x tp)	4.32	44	0.10		
sight x xtime	0.35	4	0.09	0.77	ns
(sight x xtime x tp)	4.98	44	0.11		
trial x range	0.69	2	0.35	3.26	ns
(trial x range x tp)	2.34	22	0.11		
trial x xtime	0.12	2	0.06	0.65	ns
(trial x xtime x tp)	2.03	22	0.09		
range x xtime	3.86	4	0.96	7.75	<0.05 *
(range x xtime x tp)	5.48	44	0.12		
sight x trial x range	0.14	4	0.03	0.36	ns
(sight x trial x range x tp)	4.27	44	0.10		
sight x trial x xtime	0.88	4	0.22	2.83	<0.05 **
(sight x trial x xtime x tp)	3.42	44	0.08		
sight x range x xtime	0.37	8	0.05	0.46	ns
(sight x range x xtime x tp)	8.85	88	0.10		
trial x range x xtime	0.30	4	0.07	0.59	ns
(trial x range x xtime x tp)	5.56	44	0.13		
sight x trial x range x xtime	0.45	8	0.06	0.56	ns
(sight x trial x range x xtime x tp)	8.92	88	0.10		

*Greenhouse-Geisser correction was done, but results were still significantly different.

**Sphericity was not violated.

p <0.05 indicates a significant difference; ns = not significant

Table F-2

Subtest 1. Analysis of Variance for Number of Targets Hit (double targets)

Source	SS	df	MS	F	p
tp	5.34	11	0.49		
sight	0.32	2	0.16	1.91	ns
(sight x tp)	1.82	22	0.08		
trial	0.01	1	0.01	0.06	ns
(trial x tp)	0.97	11	0.09		
range	19.70	2	9.85	88.77	<0.05 **
(range x tp)	2.44	22	0.11		
xtime	1.17	1	1.17	38.47	<0.05 *
(xtime x tp)	0.34	11	0.03		
sight x trial	0.32	2	0.16	1.93	ns
(sight x trial x tp)	1.84	11	0.08		
sight x range	0.13	4	0.03	0.34	ns
(sight x range x tp)	4.31	44	0.10		
sight x xtime	0.22	2	0.11	1.11	ns
(sight x xtime x tp)	2.17	22	0.10		
trial x range	0.01	2	0.01	0.11	ns
(trial x range x tp)	1.07	22	0.05		
trial x xtime	0.13	1	0.13	1.87	ns
(trial x xtime x tp)	0.77	11	0.07		
range x xtime	0.46	2	0.23	5.48	<0.05 **
(range x xtime x tp)	0.93	22	0.04		
sight x trial x range	0.58	4	0.15	1.60	ns
(sight x trial x range x tp)	4.00	44	0.09		
sight x trial x xtime	0.13	2	0.06	1.79	ns
(sight x trial x xtime x tp)	0.79	22	0.04		
sight x range x xtime	0.32	4	0.08	0.79	ns
(sight x range x xtime x tp)	4.46	44	0.10		
trial x range x xtime	0.22	2	0.11	2.54	ns
(trial x range x xtime by tp)	0.95	22	0.04		
sight x trial x range x xtime	0.30	4	0.07	1.94	ns
(sight x trial x range x xtime x tp)	1.78	44	0.04		

*Greenhouse-Geisser correction was done, but results were still significantly different.
**Sphericity was not violated.
p <0.05 indicates a significant difference
ns = not significant

Table F-[illegible]

Subtest I. Analysis of Variance [illegible] Time to Hit
(Single targets)

Source	SS	df	MS	F	p
TP	[illegible]	[illegible]	[illegible]		
sight	2.42	[illegible]	1.21	3.65	ns
(sight x tp)	7.29	22	0.33		
trial	1.59	1	1.59	5.08	ns
(trial x tp)	3.44	[illegible]	[illegible]		
range	[illegible]	[illegible]	[illegible]	[illegible].58	ns
(range x tp)	[illegible]	[illegible]	[illegible]		
xtime	[illegible]	[illegible]	[illegible]	[illegible]	ns
(xtime x tp)	[illegible]	[illegible]	[illegible]		
sight x trial	[illegible]	[illegible]	[illegible]	1.52	ns
(sight x trial x tp)	[illegible]	[illegible]	[illegible]		
sight x range	[illegible]	[illegible]	[illegible]	2.42	ns
(sight x range x tp)	[illegible]	[illegible]	[illegible]		
sight x xtime	[illegible]	4	[illegible]	1.74	ns
(sight x xtime x tp)	[illegible]	44	[illegible]		
trial x range	[illegible]	[illegible]	[illegible]	2.00	ns
(trial x range x tp)	[illegible]	[illegible]	[illegible]		
trial x xtime	[illegible]	[illegible]	[illegible]	2.49	ns
(trial x xtime x tp)	[illegible]	[illegible]	[illegible]		
range x xtime	[illegible]	[illegible]	[illegible]	[illegible]	ns
(range x xtime x tp)	[illegible]	[illegible]	[illegible]		
sight x trial x range	[illegible]	4	[illegible]	[illegible]	ns
(sight x trial x range x tp)	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		

[illegible]

Table F-4

Subtest 1. Analysis of Variance for Time to Hit
(double targets)

Source	SS	df	MS	F	p
tp	[illegible].06	11	0.28		
sight	0.89	2	0.45	0 72	ns
(sight x tp)	13.77	22	0.63		
trial	0.00	1	0.00	0.00	ns
(trial x tp)	[illegible]	11	[illegible]		
range	[illegible]	2	0.16	0.32	ns
(range x tp)	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible].41	ns
[illegible]	[illegible]	[illegible]	[illegible]		
sight x trial	[illegible]	[illegible]	[illegible]	0.10	ns
(sight x trial x tp)	[illegible]	[illegible]	[illegible]		
sight x range	[illegible]	4	[illegible]	1.22	ns
(sight x range x tp)	[illegible]	[illegible]	[illegible]		
sight x [illegible]	[illegible]	[illegible]	[illegible]	1.28	ns
(sight x [illegible] x tp)	[illegible]	[illegible]	[illegible]		
trial x range	[illegible]	[illegible]	[illegible]	[illegible].09	ns
(trial x range x tp)	[illegible]	[illegible]	[illegible]		
trial x [illegible]	[illegible]	[illegible]	[illegible]	0.35	ns
(trial x [illegible] x tp)	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	4	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	4	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]		

Table F-5

Subtest 1. Analysis of Variance for Time to First Shot
(Single targets)

Source	SS	df	MS	F	p
TP	11.34	11	1.03		
sight	0.30	2	0.15	1.22	ns
(sight x tp)	2.69	22	0.12		
trial	0.53	1	0.53	2.48	ns
(trial x tp)	2.35	11	0.21		
range	20.17	2	10.08	65.05	<0.05 *
(range x tp)	3.41	22	0.16		
xtime	0.69	2	0.35	3.14	ns
(xtime x tp)	2.43	22	0.11		
sight x trial	0.21	2	0.10	0.67	ns
(sight x trial x tp)	3.45	22	0.16		
sight x range	0.15	4	0.04	0.78	ns
(sight x range x tp)	2.13	44	0.05		
sight x xtime	0.78	4	0.20	1.45	ns
(sight x xtime x tp)	5.92	44	0.13		
trial x range	0.39	2	0.19	5.66	<0.05 *
(trial x range x tp)	0.75	22	0.03		
trial x xtime	0.31	2	0.15	1.17	ns
(trial x xtime x tp)	2.90	22	0.13		
range x xtime	1.28	4	0.32	4.01	ns
(range x xtime x tp)	3.52	44	0.08		
sight x trial x range	0.28	4	0.07	1.56	ns
(sight x trial x range x tp)	1.94	44	0.04		
sight x trial x xtime	[illegible]	4	0.08	1.09	ns
(sight x trial x xtime x tp)	3.12	44	0.07		
sight x range x xtime	[illegible]	4	0.02	0.16	ns
(sight x range x xtime x tp)	[illegible]	44	[illegible]		
trial x range x xtime	0.29	4	[illegible]	[illegible]	ns
(trial x range x xtime x tp)	4.14	44	[illegible]		
sight x trial x range x xtime	[illegible]	4	[illegible]	0.75	ns
(sight x trial x range x xtime x tp)	[illegible]	44	[illegible]		

*Greenhouse-Geisser correction was done, and results were still significantly different.
p <0.05 indicates a significant difference
ns = not significant

Table F-6

Subtest 1. Analysis of Variance for Time to First Shot
(double targets)

Source	SS	df	MS	F	p
tp	10.37	11	0.98		
sight	0.53	2	0.26	0.90	ns
(sight x tp)	6.42	22	0.29		
trial	2.60	1	2.60	13.47	<0.05 *
(trial x tp)	2.12	11	0.19		
range	24.68	2	12.34	74.90	<0.05 *
(range x tp)	3.63	22	0.16		
xtime	0.03	1	0.03	0.58	ns
(xtime x tp)	0.61	11	0.06		
sight x trial	0.37	2	0.18	1.11	ns
(sight x trial x tp)	3.64	22	0.18		
sight x range	0.71	4	0.18	1.82	ns
(sight x range x tp)	4.27	44	0.10		
sight x xtime	0.19	2	0.09	1.87	ns
(sight x xtime x tp)	1.09	22	0.05		
trial x range	0.89	2	0.45	6.49	<0.05 *
(trial x range x tp)	1.52	22	0.07		
trial x xtime	0.03	1	0.03	0.36	ns
(trial x xtime x tp)	0.94	11	0.09		
range x xtime	0.03	2	0.02	0.28	ns
(range x xtime x tp)	1.26	22	0.06		
sight x trial x range	0.21	4	0.05	0.77	ns
(sight x trial x range x tp)	3.04	44	0.07		
sight x trial x xtime	0.31	2	0.16	2.45	ns
(sight x trial x xtime x tp)	1.41	22	0.06		
sight x range x xtime	0.33	4	0.08	1.86	ns
(sight x range x xtime x tp)	1.99	44	0.04		
trial x range x xtime	0.17	2	0.09	1.12	ns
(trial x range x xtime x tp)	1.76	22	0.08		
sight x trial x range x xtime	0.05	4	0.01	0.19	ns
(x sight x trial x range x xtime x tp)	3.06	44	0.07		

*Greenhouse-Geisser correction was done, but results were still significantly different.
p <0.05 indicates a significant difference
ns = not significant

Table F-7

Subtest 1. Analysis of Variance for Number of Shots Fired
(Single targets)

Source	SS	df	MS	F	p
tp	3.31	11	0.30		
sight	1.64	2	0.84	2.41	ns
(sight x tp)	7.51	22	0.34		
trial	0.12	1	0.12	1.94	ns
(trial x tp)	0.71	11	0.06		
range	15.64	2	7.82	36.39	<0.05 **
(range x tp)	4.73	22	0.21		
xtime	21.57	2	10.78	40.89	<0.05 **
(xtime x tp)	5.80	22	0.26		
sight x trial	0.11	2	0.06	0.69	ns
(sight x trial x tp)	1.78	22	0.08		
sight x range	1.14	4	0.28	1.07	ns
(sight x range x tp)	11.72	44	0.27		
sight x xtime	2.54	4	0.64	3.01	<0.05 **
(sight x xtime x tp)	9.31	44	0.21		
trial x range	1.44	2	0.72	7.53	<0.05 **
(tiral x range x tp)	2.11	22	0.10		
trial x xtime	0.11	2	0.06	0.34	ns
(trial x xtime x tp)	3.56	22	0.16		
range x xtime	13.46	4	3.36	13.66	<0.05 **
(range x xtime x tp)	10.84	44	0.25		
sight x trial x range	0.06	4	0.01	0.09	ns
(sight x trial x range x tp)	7.17	44	0.16		
sight x trial x xtime	0.44	4	0.11	0.81	ns
(sight x trial x xtime x tp)	6.00	44	0.14		
sight x range x xtime	1.48	8	0.19	0.74	ns
(sight x range x xtime x tp)	22.00	88	0.25		
trial x range x xtime	0.53	4	0.13	0.52	ns
(trial x range x xtime x tp)	11.25	44	0.26		
sight x trial x range x xtime	[illegible]	8	[illegible]	[illegible]	ns
(sight x trial x range x x xtime x tp)	[illegible]	88	[illegible]		

**Sphericity was not violated.
p <0.05 indicates a significant difference
ns = not significant

Table F-8

Subtest 1. Analysis of Variance for Number of Shots Fired
(double targets)

Source	SS	df	MS	F	p
tp	1.89	11	0.17		
sight	0.49	2	0.25	3.12	ns
(sight x tp)	1.74	22	0.08		
trial	0.08	1	0.08	1.74	ns
(trial x tp)	0.53	11	0.05		
range	1.71	2	1.85	14.73	<0.05 **
(range x tp)	1.28	22	0.06		
xtime	7.52	1	7.52	44.29	<0.05 *
(xtime x tp)	1.87	11	0.17		
sight x trial	0.01	2	0.01	0.11	ns
(sight x trial x tp)	1.09	22	0.05		
sight x range	0.44	4	0.11	1.15	ns
(sight x range x tp)	4.20	44	0.10		
sight x xtime	0.21	2	0.11	1.62	ns
(sight x xtime x tp)	1.44	22	0.07		
trial x range	0.17	2	0.09	1.48	ns
(trial x range x tp)	1.26	22	0.06		
trial x xtime	0.00	1	0.00	0.00	ns
(trial x xtime x tp)	0.72	11	0.07		
range x xtime	2.28	2	1.14	14.72	<0.05 **
(range x xtime x tp)	1.70	22	0.08		
sight x trial x range	0.13	4	0.03	0.65	ns
(sight x trial x range x tp)	2.23	44	0.05		
sight x trial x xtime	0.23	2	0.12	1.39	ns
(sight x trial x xtime x tp)	1.84	22	0.08		
sight x range x xtime	0.26	4	0.06	1.28	ns
(sight x range x xtime x tp)	2.22	44	0.05		
trial x range x xtime	0.11	2	0.05	1.35	ns
(trial x range x xtime x tp)	0.88	22	0.04		
sight x trial x range x xtime	0.47	4	0.12	1.48	ns
(tp x sight x trial x range x xtime)	3.50	44	[illegible]		

*Greenhouse-Geisser correction was done, but results were still significantly different.

**Sphericity was not violated.

p <0.05 indicates a significant difference

ns = not significant

Table F-9

Subtest 2. Analysis of Variance for Number of Targets Hit (single targets)

Source	SS	df	MS	F	p
ll	6.14	3	2.05	2.44	ns
(tp w ll)	6.74	8	0.84		
sight	0.47	3	0.16	0.80	ns
sight x ll	2.44	9	0.27	1.37	ns
(sight x tp w ll)	4.55	23	0.20		
range	15.75	2	7.88	44.70	<0.05 *
range x ll	2.44	6	0.41	2.31	ns
(range x tp w ll)	2.82	16	0.18		
range x sight	1.19	6	0.20	1.60	ns
range x sight x ll	3.39	18	0.19	1.52	ns
(range x sight x tp w ll)	5.71	46	0.12		
xtime	3.00	2	1.50	11.14	<0.05 *
xtime x ll	0.94	6	0.16	1.17	ns
(xtime x tp w ll)	2.16	16	0.13		
xtime x range	2.19	4	0.55	3.61	ns
xtime x range x ll	1.03	12	0.09	0.57	ns
(xtime x range x tp w ll)	4.85	32	0.15		
xtime x sight	0.28	6	0.05	0.41	ns
xtime x sight x ll	1.56	18	0.09	0.77	ns
(xtime x sight x tp w ll)	5.38	48	0.11		
xtime x sight x range	0.37	12	0.03	0.21	ns
xtime x sight x range x ll	3.30	36	0.09	0.63	ns
(xtime x sight x range x tp w ll)	14.04	96	0.15		

*Greenhouse-Geisser correction was done, but results were still significantly different.

$p < 0.05$ indicates a significant difference

ns = not significant

Table F-10

Subtest 2. Analysis of Variance for Number of Targets Hit (double targets)

Source	SS	df	MS	F	p
ll	5.14	3	1.71	4.04	ns
(tp w ll)	3.39	8	0.42		
sight	0.29	3	0.10	0.70	ns
sight x ll	0.64	9	0.07	0.51	ns
(sight x tp w ll)	3.21	23	0.14		
range	11.29	2	5.65	45.52	<0.05 *
range x ll	2.27	6	0.38	3.05	ns
(range x tp w ll)	1.98	16	0.12		
range x sight	0.58	6	0.10	1.75	ns
range x sight x ll	1.27	18	0.07	1.27	ns
(range x sight x tp w ll)	2.56	46	0.06		
xtime	0.63	1	0.63	7.79	<0.05 *
xtime x ll	0.23	3	0.08	0.97	ns
(xtime x tp w ll)	0.65	8	0.08		
xtime x range	0.07	2	0.04	0.48	ns
xtime x range x ll	0.41	6	0.07	0.90	ns
(xtime x range x tp w ll)	1.21	16	0.08		
xtime x sight	0.56	3	0.19	1.92	ns
xtime x sight x ll	0.83	9	0.09	0.95	ns
(xtime x sight x tp w ll)	2.23	24	0.10		
xtime x sight x range	0.18	6	0.03	0.47	ns
xtime x sight x range x ll	0.84	18	0.05	0.72	ns
(xtime x sight x range x tp w ll)	3.10	48	0.06		

*Greenhouse-Geisser correction was done, but results were still significantly different.

p <0.05 indicates a significant difference

ns = not significant

Table F-11

Subtest 2. Analysis of Variance for Time to Hit (single targets)

Source	SS	df	MS	F	p
ll	2.00	3	0.67	0.77	ns
(tp w ll)	7.00	8	0.87		
sight	1.64	3	0.55	0.85	ns
sight x ll	4.81	9	0.53	0.83	ns
(sight x tp w ll)	14.79	23	0.64		
range	9.26	2	4.63	13.31	<0.05 *
range x ll	1.76	6	0.29	0.84	ns
(range x tp w ll)	5.57	16	0.35		
range x sight	1.04	6	0.17	0.42	ns
range x sight x ll	5.39	15	0.36	0.88	ns
(range x sight x tp w ll)	15.39	39	0.41		
xtime	5.93	2	2.96	4.21	ns
xtime x ll	5.02	6	0.84	1.19	ns
(xtime x tp w ll)	11.27	16	0.70		
xtime x range	7.20	4	1.80	4.15	ns
xtime x range x ll	6.99	11	0.64	1.47	ns
(xtime x range x tp w ll)	11.27	26	0.43		
xtime x sight	5.90	6	0.98	1.65	ns
xtime x sight x ll	16.33	18	0.91	1.52	ns
(xtime x sight x tp w ll)	28.61	48	0.60		
xtime x sight x range	12.34	12	1.03	1.75	ns
xtime x sight x range x ll	30.97	36	0.86	1.46	ns
(xtime x sight x range x tp w ll)	55.76	95	0.59		

*Greenhouse-Geisser correction was done, but results were still significantly different.

p <0.05 indicates a significant difference

ns = not significant

Table F-12

Subtest 2. Analysis of Variance for Time to Hit (double targets)

Source	SS	df	MS	F	p
ll	1.14	3	0.38	1.90	ns
(tp w ll)	1.59	8	0.20		
sight	1.07	3	0.36	0.77	ns
sight x ll	3.52	9	0.39	0.85	ns
(sight x tp w ll)	10.61	23	0.46		
range	0.06	2	0.03	0.09	ns
range x ll	4.59	6	0.76	2.09	ns
(range x tp w ll)	5.86	16	0.37		
range x sight	0.78	6	0.13	0.32	ns
range x sight x ll	6.21	18	0.35	0.85	ns
(range x sight x tp w ll)	15.93	39	0.41		
xtime	5.04	1	5.04	10.23	<0.05 *
xtime x ll	1.03	3	0.34	0.70	ns
(xtime x tp w ll)	3.94	8	0.49		
xtime x range	1.02	2	0.51	1.16	ns
xtime x range x ll	1.81	6	0.30	0.69	ns
(xtime x range x tp w ll)	6.14	14	0.44		
xtime x sight	1.11	3	0.37	1.06	ns
xtime x sight x ll	5.68	9	0.63	1.80	ns
(xtime x sight x tp w ll)	8.06	23	0.35		
xtime x sight x range	4.25	6	0.71	1.50	ns
xtime x sight x range x ll	3.54	18	0.20	0.42	ns
(xtime x sight x range x tp w ll)	21.68	46	47		

*Greenhouse-Geisser correction was done, but results were still significantly different.
p <0.05 indicates a significant difference
ns = not significant

Table F-13

Subtest 2. Analysis of Variance for Time to First Shot
(single targets)

Source	SS	df	MS	F	p
ll	13.31	3	4.44	2.80	ns
(tp w ll)	12.68	8	1.58		
sight	1.42	3	0.47	2.47	ns
sight x ll	5.83	9	0.65	3.39	ns
(sight x tp w ll)	4.39	23	0.19		
range	19.76	2	9.88	69.27	<0.05 *
range x ll	1.92	6	0.32	2.25	ns
(range x tp w ll)	2.28	16	0.14		
range x sight	0.55	6	0.09	0.96	ns
range x sight x ll	2.74	18	0.15	1.60	ns
(range x sight x tp w ll)	4.40	46	0.10		
xtime	1.46	2	0.73	6.88	<0.05 *
xtime x ll	1.75	6	0.29	2.74	ns
(xtime x tp w ll)	1.70	16	0.11		
xtime x range	2.30	4	0.58	4.95	ns
xtime x range x ll	5.38	12	0.45	3.85	ns
(xtime x range x tp w ll)	3.72	32	0.12		
xtime x sight	0.56	6	0.09	0.58	ns
xtime x sight x ll	2.59	18	0.14	0.88	ns
(xtime x sight x tp w ll)	7.79	48	0.16		
xtime x sight x range	2.02	12	0.17	1.02	ns
xtime x sight x range x ll	6.06	36	0.17	1.02	ns
(xtime x sight x range x tp w ll)	15.84	96	0.17		

*Greenhouse-Geisser correction was done, but results were still significantly different.

p <0.05 indicates a significant difference

ns = not significant

Table F-14

Subtest 2. Analysis of Variance for Time to First Shot (double targets)

Source	SS	df	MS	F	p
ll	16.93	3	5.64	3.64	ns
(tp w ll)	12.38	8	1.55		
sight	4.25	3	1.42	7.35	<0.05 *
sight x ll	5.10	9	0.57	2.94	ns
(sight x tp w ll)	4.43	23	0.19		
range	12.13	2	6.06	60.99	<0.05 *
range x ll	1.72	6	0.29	2.89	ns
(range x tp w ll)	1.59	16	0.10		
range x sight	0.53	6	0.09	1.09	ns
range x sight x ll	2.18	18	0.12	1.48	ns
(range x sight x tp w ll)	3.73	46	0.08		
xtime	0.11	1	0.11	0.91	ns
xtime x ll	1.01	3	0.34	2.74	ns
(xtime x tp w ll)	0.98	8	0.12		
xtime x range	0.08	2	0.04	0.62	ns
xtime x range x ll	0.23	6	0.04	0.61	ns
(xtime x range x tp w ll)	0.99	16	0.06		
xtime x sight	0.07	3	0.02	0.46	ns
xtime x sight x ll	0.73	9	0.08	1.67	ns
(xtime x sight x tp w ll)	1.11	23	0.05		
xtime x sight x range	0.52	6	0.09	1.12	ns
xtime x sight x range x ll	1.13	18	0.06	0.81	ns
(xtime x sight x range x tp w ll)	3.70	48	0.08		

*Greenhouse-Geisser correction was done, but results were still significantly different.

p <0.05 indicates a significant difference

ns = not significant

Table F-15

Subtest 2. Scheffé's Test for Mean Time to First Shot (double targets)

alpha = 0.05 df = 23 MSE = 0.19

	Mean	Group	Grp 3	Grp 4	Grp 1	Grp 2
visible laser	1.1417	Grp 3				
aimpoint	1.2834	Grp 4				
iron sights	1.3831	Grp 1	*			
tritium three-dot	1.3997	Grp 2	*			

* Denotes pairs of groups significantly different

Table F-16

Subtest 2. Analysis of Variance for Number of Shots Fired (single targets)

Source	SS	df	MS	F	P
11	1.87	3	0.62	0.68	ns
(tp w 11)	7.34	8	0.92		
sight	5.09	3	1.70	4.62	ns
sight x 11	2.64	9	0.29	0.80	ns
(sight x tp w 11)	8.44	23	0.37		
range	5.26	2	2.63	7.67	<0.05 *
range x 11	2.41	6	0.40	1.17	ns
(range x tp w 11)	5.48	[illegible]	0.34		
range x sight	1.27	6	0.21	1.11	ns
range x sight x 11	7.62	18	0.42	2.23	ns
(range x sight x tp w 11)	8.75	46	0.19		
xtime	18.22	2	9.11	16.70	<0.05 *
xtime x 11	4.37	6	0.73	1.34	ns
(xtime x tp w 11)	8.72	16	0.55		
xtime x range	8.08	4	2.02	7.54	[illegible] *
xtime x range x 11	5.01	12	0.42	1.56	ns
(xtime x range x tp w 11)	8.57	32	0.27		
xtime x sight	1.96	6	0.33	1.89	ns
xtime x sight x 11	1.99	18	0.11	0.63	ns
(xtime x sight x tp w 11)	8.37	48	0.17		
xtime x sight x range	3.56	12	0.30	1.55	ns
xtime x sight x range x 11	6.47	36	0.24	1.23	ns
(xtime x sight x range x tp w 11)	18.41	[illegible]	0.19		

*Greenhouse-Geisser correction was done, but results were still significantly different.

p <0.05 indicates a significant difference

ns = not significant

Table F-17

Subtest 2. Analysis of Variance for Number of Shots Fired (double targets)

Source	SS	df	MS	F	p
ll	0.13	3	0.04	0.16	ns
(tp w ll)	1.98	8	0.25		
sight	0.70	3	0.23	2.31	ns
sight x ll	1.90	9	0.21	2.08	ns
(sight x tp w ll)	2.33	23	0.10		
range	0.76	2	0.38	3.25	ns
range x ll	0.97	6	0.16	1.38	ns
(range x tp w ll)	1.87	16	0.12		
range x sight	1.11	6	0.19	2.69	ns
range x sight x ll	1.99	18	0.11	1.60	ns
(range x sight x tp w ll)	3.18	46	0.07		
xtime	5.17	1	5.17	58.84	<0.05 *
xtime x ll	1.61	3	0.54	6.10	ns
(xtime x tp w ll)	0.70	8	0.09		
xtime x range	1.91	2	0.95	11.67	<0.05 *
xtime x range x ll	0.61	6	0.10	1.25	ns
(xtime x range x tp w ll)	1.31	16	0.08		
xtime x sight	0.20	3	0.07	0.92	ns
xtime x sight x ll	2.25	9	0.25	3.06	ns
(xtime x sight x tp w ll)	1.88	23	0.08		
xtime x sight x range	0.86	6	0.14	1.95	ns
xtime x sight x range x ll	1.95	18	0.11	1.39	ns
(xtime x sight x range x tp w ll)	3.73	48	0.08		

*Greenhouse-Geisser correction was done, but results were still significantly different.
p <0.05 indicates a significant difference
ns = not significant

Table F-18

Subtest 3. Analysis of Variance for Number of Targets Hit
(single targets)

Source	SS	df	MS	F	p
TP	5.16	11	0.47		
sight	14.88	6	2.48	13.12	<0.05**
(sight x tp)	12.48	66	0.19		
range	45.88	2	22.94	98.34	<0.05*
(range x tp)	5.13	22	0.23		
xtime	11.92	2	5.96	102.22	<0.05**
(xtime x tp)	1.28	22	.06		
sight x range	4.28	12	0.36	2.58	<0.05*
(sight x range x tp)	18.26	132	0.14		
sight x xtime	2.80	12	0.23	1.90	ns
(sight x time x tp)	16.22	132	0.12		
range x xtime	1.95	4	0.49	5.95	<0.05**
(range x xtime by tp)	3.61	44	0.08		
sight x range xtime	4.77	24	0.20	1.48	ns
(sight x range x xtime x tp)	35.45	264	0.13		

*Greenhouse-Geisser correction was done, but results were still significantly different.

**Sphericity was not violated.

p <0.05 indicates a significant difference

ns = not significant

Table F-19

Subtest 3. Scheffé's Test for Hits per Target Opportunity by Sight (single targets)

Source	SS	df	MS	F	p

alpha = 0.05 df = 66 MSE = 0.19

	Mean	Group	Grp 2	Grp 7	Grp 1	Grp 3	Grp 4	Grp 5	Grp 6
iron-nvg	0.2500	Grp 2							
aimpoint	0.3148	Grp 7							
iron	0.3333	Grp 1							
tritium three-dot	0.3333	Grp 3							
visible laser	0.4630	Grp 4							
visible laser-nvg	0.6019	Grp 5	*	*	*	*			
irr-nvg	0.6389	Grp 6	*	*	*	*			

* Denotes pairs of groups significantly different

Table F-20

Subtest 3. Analysis of Variance for Number of Targets Hit (double targets)

Source	SS	df	MS	F	p
TP	3.21	11	0.29		
sight	10.53	6	1.76	13.88	<0.05**
(sight x tp)	8.35	66	0.13		
range	39.50	2	19.75	174.85	<0.05**
(range x tp)	2.49	22	0.11		
xtime	1.05	1	1.05	46.55	<0.05*
(xtime x tp)	0.25	11	0.02		
sight x range	3.80	12	0.32	3.50	<0.05*
(sight x range x tp)	11.56	132	0.09		
sight x xtime	0.31	6	0.05	1.09	ns
(sight x time x tp)	3.14	66	.05		
range x xtime	0.51	2	0.25	4.49	<0.05**
(range x xtime x tp)	1.27	22	0.06		
sight x range xtime	0.59	12	0.05	0.88	ns
(sight x range x time x tp)	7.39	132	0.06		

*Greenhouse-Geisser correction was [illegible] different.

**Sphericity was not violated.

p <0.05 indicates a significant difference

ns = not significant

Table F-21

Subtest 3. Scheffé's Test for Hits per Target Opportunity by Sight (double targets)

alpha = 0.05 df = 66 MSE = 0.13

	Mean	Group	Grp 2	Grp 3	Grp 1	Grp 7	Grp 4	Grp 5	Grp 6
iron-nvg	0.2569	Grp 2							
tritium three-dot	0.3333	Grp 3							
iron	0.3403	Grp 1							
aimpoint	0.3889	Grp 7							
visible laser	0.4236	Grp 4							
visible laser-nvg	0.6250	Grp 5	*	*	*	*			
irr-nvg	0.6736	Grp 6	*	*	*	*	*		

* Denotes pairs of groups significantly different

Table F-22

Subtest 3. Analysis of Variance for Time to Hit
(single targets)

Source	SS	df	MS	F	p
TP	2.77	11	0.25		
sight	5.64	6	0.94	1.61	ns
(sight x tp)	37.40	64	0.53		
range	1.82	2	0.91	2.30	ns
(range x tp)	7.90	20	0.40		
xtime	0.12	2	0.06	0.08	ns
(xtime x tp)	16.24	22	0.74		
sight x range	5.53	11	0.50	0.71	ns
(sight x range x tp)	33.24	47	0.71		
sight x xtime	18.22	12	1.52	2.07	ns
(sight x time x tp)	95.15	130	0.73		
range x xtime	5.76	4	1.44	3.62	ns
(range x xtime x tp)	8.35	21	0.40		
sight x range x xtime	22.43	24	0.93	0.98	ns
(sight x range x xtime x tp)	219.36	229	0.96		

$p < 0.05$ indicates a significant difference
ns = not significant

Table F-23

Subtest 3. Analysis of Variance for Time to Hit (double targets)

Source	SS	df	MS	F	p
TP	9.88	11	0.90		
sight	4.79	6	0.80	0.96	ns
(sight x tp)	52.94	64	0.83		
range	3.52	2	1.76	1.81	ns
(range x tp)	20.40	21	0.97		
xtime	2.73	1	2.73	3.38	ns
(xtime x tp)	8.89	11	0.81		
sight x range	8.58	11	0.78	1.23	ns
(sight x range x tp)	27.90	44	0.63		
sight x xtime	3.78	6	0.63	0.99	ns
(sight x time x tp)	35.61	56	0.64		
range x xtime	1.38	2	0.69	1.22	ns
(range x xtime x tp)	9.04	16	0.57		
sight x range x xtime	4.28	8	0.54	0.93	ns
(sight x range x xtime x tp)	9.82	17	0.58		

p <0.05 indicates a significant difference
ns = not significant

Table F-24

Subtest 3. Analysis of Variance for Time to First Shot
(single targets)

Source	SS	df	MS	F	p
TP	2.16	11	0.20		
sight	1.79	6	0.30	0.79	ns
(sight x tp)	24.82	66	0.38		
range	16.89	2	8.44	36.33	<0.05 *
(range x tp)	5.11	22	0.23		
xtime	2.63	2	1.32	4.67	ns
(xtime x tp)	6.20	22	0.28		
sight x range	7.41	12	0.62	1.94	ns
(sight x range x tp)	32.41	102	0.32		
sight x xtime	3.19	12	0.27	1.50	ns
(sight x xtime x tp)	22.86	129	0.18		
range x xtime	2.[illegible]	4	0.54	2.[illegible]	ns
(range x xtime x tp)	9.16	44	0.[illegible]		
sight x range xtime	16.87	24	0.70	2.06	ns
(sight x range x xtime x tp)	88.69	263	0.34		

*Greenhouse-Geisser correction was done, but results were still significantly different.
p <0.05 indicates a significant difference
ns = not significant

Table F-25

Subtest 3. Analysis of Variance for Time to First Shot (double targets)

Source	SS	df	MS	F	p
sight	1.63	6	0.27	0.98	ns
(sight x tp)	18.32	66	0.28		
range	0.61	2	0.31	1.14	ns
(range x tp)	5.89	22	0.27		
xtime	0.00	1	0.00	0.01	ns
(xtime x tp)	1.103	[illegible]	0.09		
sight x range	6.12	12	0.51	3.34	ns
(sight x range x tp)	16.36	107	0.15		
sight x xtime	0.40	6	0.07	0.82	ns
(sight x xtime x tp)	5.40	66	0.08		
range x xtime	0.00	2	0.00	[illegible]	ns
(range x xtime x tp)	3.27	22	[illegible]		
sight x range x xtime	0.84	12	0.07	0.72	ns
(sight x range x xtime x tp)	8.85	[illegible]	0.10		

$p < 0.05$ indicates a significant difference

ns = not significant

Table F-26

Subtest 3. Analysis of Variance for Number of Shots Fired (single targets)

Source	SS	df	MS	F	p
TP	12.01	11	1.09		
sight	73.93	6	12.32	14.59	<0.05**
(sight x tp)	55.75	66	0.84		
range	47.32	2	23.66	35.53	<0.05**
(range x tp)	14.65	22	0.67		
xtime	67.33	2	33.66	60.27	<0.05**
(xtime x tp)	12.28	22	0.56		
sight x range	69.99	12	5.83	13.91	<0.05*
(sight x range x tp)	56.37	132	0.43		
sight x xtime	14.34	12	1.20	3.59	<0.05*
(sight x xtime x tp)	44.07	132	0.33		
range x xtime	7.62	4	1.91	[illegible]	<0.05**
(range x xtime by tp)	8.37	44	0.19		
sight x range xtime	16.35	24	0.68	1.97	ns
(sight x range x xtime x tp)	91.05	264	0.34		

*Greenhouse-Geisser correction was used, but results were still significantly different.

**Sphericity was not violated.

p <0.05 indicates a significant difference

ns = not significant

Table F-27

Subtest 3. Scheffé's Test for Shots per Target Opportunity by Sight (single targets)

Source	SS	df	MS	F	p

alpha = 0.05 df = 66 MSE = 0.84

	Mean	Group	Grp 4	Grp 3	Grp 7	Grp 1	Grp 5	Grp 6	Grp 2
visible laser	0.7407	Grp 4							
tritium three-dot	0.7685	Grp 3							
aimpoint	0.8889	Grp 7							
iron	1.0833	Grp 1							
visible laser-nvg	1.2407	Grp 5	*	*					
irr-nvg	1.2963	Grp 6	*	*					
iron-nvg	1.6852	Grp 2	*	*	*	*			

* Denotes pairs of groups significantly different

Table F-28

Subtest 3. Analysis of Variance for Number of Shots Fired
(double targets)

Source	SS	df	MS	F	p
TP	4.76	11	0.43		
sight	32.45	6	5.41	15.27	<0.05**
(sight x tp)	23.38	66	0.35		
range	33.25	2	16.62	65.09	<0.05**
(range x tp)	5.67	22	0.26		
xtime	11.76	1	[illegible]	[illegible]	<0.05*
(xtime x tp)	1.65	11	0.15		
sight x range	[illegible]	12	2.14	[illegible]	[illegible]
(sight x range x tp)	22.16	132	[illegible]		
sight x xtime	[illegible]	6	[illegible]	[illegible]	[illegible]
(sight x xtime by tp)	[illegible]	66	[illegible]		
range x xtime	[illegible]	2	[illegible]	[illegible]	[illegible]
(range x xtime by tp)	[illegible]	22	[illegible]		
sight x range xtime	[illegible]	12	[illegible]	[illegible]	[illegible]
(sight x range x xtime x tp)	[illegible]	132	[illegible]		

*Greenhouse-Geisser correction [illegible]
different.

**Sphericity was not violated.

p <0.05 indicates a significant difference

ns = not significant

Table F-29

Subtest 3. Scheffé's Test for Shots per Target Opportunity by Sight (double targets)

alpha = 0.05 df = 66 MSE = 0.35

	Mean	Group	Grp 4	Grp 3	Grp 7	Grp 1	Grp 5	Grp 6	Grp 2
visible laser	0.7500	Grp 4							
tritium three-dot	0.7847	Grp 3							
aimpoint	0.8472	Grp 7							
iron	1.0000	Grp 1							
visible laser-nvg	1.0764	Grp 5							
irr-nvg	1.1181	Grp 6	*						
iron-nvg	1.5486	Grp 2	*	*	*	*	*	*	

* Denotes pairs of groups significantly different