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EFFECTIVE STINGER TRAINING IN RADES

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Introduction and Background

Air Defense Training Problems

Realistic, collective training of Forward Area Air Defense (FAAD) units is essential for combat readiness. However, the air defense artillery (ADA) community has a limited number of options currently available for pursuit of this requirement. Training simulators, such as the Moving Target Simulator (MTS), do not allow the conduct of collective training and introduce artifacts not representative of the true combat environment. Field test exercises are always resource intensive (costly), are difficult to control, and usually do not provide realistic threat targets or accurate and rapid corrective instructional feedback.

The U.S. Army National Training Center (NTC) at Fort Irwin, California employs scaled threat aircraft against weapons firing live rounds or using the Multiple Integrated Laser Engagement System (MILES). NTC allows greater realism than do conventional FTX applications and provides greater control, and more accurate and rapid feedback. Yet NTC is resource intensive, heavily scheduled, and provides limited opportunity to train FAAD crews/teams. In this regard, NTC cannot be an effective and efficient vehicle for the comprehensive, collective training of air defense units.

The solution to the problem is for the air defense community to develop its own, requirements-driven, collective training system. The system must provide valid, reliable, realistic, practical, and economic training with accurate, rapidly-available feedback. The needed system should provide dozens of training trials each day, under varying atmospheric conditions, for most days of the year. The system needed should be sufficiently flexible to allow the training of single fire units, squads/sections, and/or a platoon. Finally, the training system should not burden the air defense community with unreasonably high demands for resources (dollars, equipment, personnel, space, and time).

A Potential Solution to the Training Problems

The Realistic Air Defense Engagement System (RADES) is a valid (Drewfs, Barber, Johnson & Frederickson, in press) FAAD testbed located in the desert at White Sands Missile Range, New Mexico. RADES was designed and developed, and is currently operated and maintained by Science Applications International Corporation (SAIC) on behalf of the Army Research Institute (ARI). RADES employs actual FAAD units and their weapons in simulated engagements of 1/7 scale, flying, fixed-wing (FW) and 1/5 scale, "pop-up", rotary-wing (RW) targets. RADES uses subscale aircraft, and thus only requires about 1/5th of the land area required by comparable full-scale field test exercises.

Currently, RADES can provide dozens of realistic, collective training trials, with accurate feedback every fair weather day. However, RADES cannot operate during heavy winds or precipitation. RADES is capable of training one fire unit at a time (to be upgraded to five). RADES requires a compliment of approximately twelve fulltime personnel to support the training of that fire unit.

RADES provides Short Range Air Defense (SHORAD) soldiers the opportunity to practice and to generalize part-task engagement behaviors in a representative combat environment. Criterion-guided instructor feedback can be focused on the soldier's and team's responses during realistic fixed and rotary-wing aircraft scenarios. Learning obtained from the classroom and part-task trainers can be further enhanced using the whole-task environment of RADES. The knowledge and skills of the soldier can be shaped into meaningful soldier behaviors using RADES. If RADES successfully "trains", engagement event reaction times will be reduced, engagement event ranges will be increased, and target identification accuracy will be improved. This study and subsequent RADES training applications will be dedicated to answering the question, "Does RADES train?".

In the current configuration, RADES cannot provide a complete solution to the air defense collective training problem. RADES requires too many resources, to train too few units, during too few days of the year. Some of these shortfalls can and are being corrected. Before undertaking the modification of RADES into a collective unit trainer, however, it becomes necessary to assess the effectiveness of RADES in specific types of training applications.

Training Effectiveness Issues

First, a trainer must be shown to produce a positive change in performance as a result of reinforced practice and feedback. That is, a subject team should perform superior to its entry level criterion measure scores, and should demonstrate a systematic learning gain across a set of repeated trials as a result of training. In such repeated measures testing, the subject team acts as its own control; responses to the treatments are measured in terms of deviations about a point which measures the average performance of that individual team (Winer, 1971; Kerlinger & Pedhazur, 1973).

The second issue is that the training, so obtained, must be valid (i.e., what is purported to be trained is actually trained). Are RADES-trained air defenders better than non-RADES-trained air defenders? This seemingly obvious question is difficult to answer definitively. Validation of training in combat arms ultimately requires simulated warfare. RADES is currently the most valid and realistic Forward Area Air Defense simulation available. However, RADES validity as a trainer may be limited to ecological, or face validity.

The third issue is characterized by the question, "Is the training achieved using RADES more cost effective than existing and competing alternatives?" This issue poses a dilemma for ARI, as no existing trainer or facility purports to train all of the same engagement event efficiency and effectiveness factors that RADES does.

Given the aforementioned issues, ARI has focused on the first training issue: the training effect. ARI needs to know if training with RADES produces a reliable increment in part-task and whole-task air defense engagement performance. The first of two studies planned to investigate the training effect issue is the current Stinger training study. The second study will be the Multiple RADES Stinger training study.

Method

The present study investigated the performance of Stinger teams during air defense simulations using the Realistic Air Defense Engagement System. Effects of repeated trials, training, and feedback on measures of aircraft engagement response times, response ranges, and response accuracy were analyzed.

The primary objective of the test was to provide realistic and representative scenarios to soldiers for practice and rehearsal of their air defense knowledge and skills. Secondary to this was the objective of measuring improvements in performance using a repeated measures design. In order to provide sufficient and continuing training to the troops, some compromises to the second objective occurred resulting in missing fixed-wing data. Therefore, only rotary-wing data were used in the repeated measures comparisons. Due to a small sample size, statistical tests used were non-parametric (sign and Wilcoxon matched pairs tests); a one-tailed alpha of .1 was designated as the criterion for statistical significance in testing the hypothesis that performance in the posttest would be superior to that of the pretest.

Fourteen scenario treatments (trials) were administered to each team, each followed by corrective instructional feedback. Training feedback lessons were administered by a platoon sergeant, to prevent experimenter intervention. The training scenario treatments were grouped into four training experiments. These training experiments differed in the type of aircraft stimuli used and the number of aircraft presented. The four experiments have been described in Table 1. All ten teams received an equivalent form of each experiment.

Table 1
Repeated Trial Training Experiments

Experiment	1	2	3	4
Targets	SFW	SRW	SEQMRW	SIMMRW

SFW = Single Fixed-Wing Scenarios.

SRW = Single Rotary-Wing Scenarios.

SEQMRW = Sequential Multiple Rotary-Wing Scenarios. These served as pretest and posttest scenarios.

SIMMRW = Simultaneous Multiple Rotary-Wing Scenarios.

Each of the four training experiments represented a combination of equivalent scenarios and target presentations (see Table 2). For purposes of analysis, the double and triple simultaneous rotary-wing treatments were combined into a single experiment, called Experiment 4. Doing this increased the number of cases for 1st and 2nd target engagements, without compromise to 3rd target engagements.

The fourteen scenarios for each scenario set are described in Table 2. In Table 2 the fixed-wing (FW) scenario patterns of 11, 12 and 1 o'clock, refer to the approach azimuth of these target stimuli, relative to the Stinger weapon position. In the case of rotary-wing (RW) experiments, the pattern refers to one of six helicopter target stands labeled by the numbers 2 to 7. Stand 2 is the leftmost stand and stand 7 is the rightmost stand, relative to the central weapon position. Helicopter target numbering proceeded from left to right in numeric order. Helicopter stands were approximately equal distance from the weapon position, at a constant range of 600 meters (1/5 scale) equating to 3,000 full-scale meters.

Table 2
Stinger Training Scenarios

Scenario No.		Target/Pattern		Aircraft	Presentation	Duration
Set 1	Set 2	Set 1	Set 2			
1	15	11o'clk	11o'clk	MIG-27	SINGLE	N/A
2	16	12o'clk	12o'clk	SU-25	SINGLE	N/A
3	17	1o'clk	1o'clk	A-7	SINGLE	N/A
4	18	12o'clk	12o'clk	A-10	SINGLE	N/A
5	19	7	3	AH-1	SINGLE	20 SECS
6	20	2	7	UH-1	SINGLE	20 SECS
7	21	4	4	CH-3	SINGLE	20 SECS
8	22	6	2	MI-24	SINGLE	20 SECS
9	23	3	6	MI-28	SINGLE	20 SECS
10	24	5	5	MI-8	SINGLE	20 SECS
11	25	5,7	5,3	MI-8; AH-1	SEQUENTIAL	20 SECS
12	26	4,3	4,6	CH-3; MI-28	SEQUENTIAL	20 SECS
13	27	6,3	2,6	MI-24; MI-28	SIMULTANEOUS	40 SECS
14	28	2,4,6	7,4,2	UH-1; CH-3 MI-24	SIMULTANEOUS	40 SECS

NOTE: RW targets 2 and 3 were at 11 o'clock;
RW targets 4 and 5 were at 12 o'clock;
RW targets 6 and 7 were at 1 o'clock.

Participating Stinger teams were divided into two groups: the morning group and the afternoon group. Morning group teams received the first set of fourteen scenarios, and the afternoon group received an equivalent set of these fourteen scenarios. The scenario training sets were administered to the teams at alternating times of day, as shown in Table 3.

Table 3
Morning and Afternoon Groups

DAY	MORNING	TEAM	AFTERNOON	TEAM
1	SET 1	1	SET 2	2
2	SET 2	3	SET 1	4
3	SET 1	5	SET 2	6
4	SET 2	7	SET 1	8
5	SET 1	9	SET 2	10

Fixed-wing aircraft (1/7 scale) flew at a constant rate of 98 miles per hour, (which equates to about 600 knots full-scale). Fixed-wing targets maintained a constant altitude of about 50 to 75 feet, approximating a full scale altitude of 350 to 525 feet. Fixed-wing aircraft turned into the engagement zone at an equivalent full-scale range of 18,500 meters to 20,000 meters and came to within 1,000 to 1,500 full-scale meters of the weapon position prior to turning from the inbound to the outbound flight-path segment.

The order of scenario treatment presentations was randomized, except for the pretest scenarios (scenario 11 and the equivalent form 25), which were always presented first, and the posttest scenarios (scenario 12 and the equivalent scenario 26), which were always presented last. Table 4 depicts the scenario order of presentation for the training treatments for each team. It should be noted that in all cases but the fixed-wing scenarios, (i.e., scenarios 1-4 and scenarios 15-18), the order of scenario administration was maintained. The fixed-wing aircraft were presented on an as-available basis.

Table 4
Stinger Training Scenario Order

SET 1 SCENARIOS														
ORDER ----- TEAM	1ST	2ND	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11TH	12TH	13TH	14TH
1	11	5	13	2	10	8	3	1	6	4	7	14	9	12
4	11	9	4	2	14	1	3	6	10	8	13	5	7	12
5	11	3	5	1	7	6	14	9	8	4	10	2	13	12
8	11	7	1	6	9	14	8	2	3	13	10	5	4	12
9	11	4	2	9	8	7	6	10	13	3	5	14	1	12

SET 2 SCENARIOS														
ORDER ----- TEAM	1ST	2ND	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11TH	12TH	13TH	14TH
2	25	15	17	24	23	20	16	27	28	22	21	18	19	26
3	25	24	17	22	16	15	20	19	27	23	28	18	21	26
6	25	15	19	18	23	24	22	17	16	20	27	28	21	26
7	25	17	21	18	23	19	20	28	24	22	16	15	27	26
10	25	20	21	15	22	27	18	23	24	28	17	19	16	26

Dependent Measures

The dependent measures were task performance measures, performance effectiveness measures, and summary performance measures. Engagement task performance measures, defined in Table 5, included the range and time of target detection, acquisition, interrogation, identification, engagement command, lock-on, and fire. Performance effectiveness measures included percent targets detected, identified, identified correctly, engaged, destroyed, and handed-off correctly. Summary performance measures included the ratio of hostiles destroyed to available hostiles (percent attrition), ratio of friendlies destroyed to available friendlies (percent fratricide), and percent of hostiles delivering ordnance (asset vulnerability). This last measure was based on ordnance delivery time or range, time or range of weapon fire, and elapsed time or range to missile-target intercept. RW ordnance release time was designated arbitrarily as 18 seconds from availability. FW ordnance release range was designated arbitrarily as 4 kilometers from the weapon.

Participants

Participants in the present study were ten Stinger teams, consisting of one team leader and one gunner each, from the U.S. Army Air Defense Artillery School (USAADASCH), Fort Bliss, Texas. Soldiers averaged about five months in the service, and three and a half months in their MOS. Table 6 provides descriptive statistics in terms of age and visual capabilities measured using the RADES Vision Testing System. These data, along with performance data, were used by personnel from the School Brigade, TSM-FAAD, Air Defense Board, and ARI to balance samples of soldiers participating in a subsequent "shoot off" test of alternative Pedestal Mounted Stinger weapon systems. It should be noted that the Stinger team members were recent graduates of Advanced Individual Training, U.S. Army Air Defense Artillery Training Center, Fort Bliss, Texas. The assignment of positions within the teams was random.

Table 5
Dependent Variables

CODE	TITLE/DESCRIPTION	DUTY	INTERPRETATION
IDCOR	Correctness of Identification	TL	Number of correct identifications divided by number of targets identified
RDET	Range of Detection	TL or G	The slant range from the weapon to the target when the event took place; greater ranges usually indicate better performance for detection and identification but not always for the other events (target can be inbound or outbound). Range is relevant for fixed-wing targets only since rotary-wing targets simply popped-up from a static position
RID	Range of Identification	TL	
RENG	Range of Command to Engage	TL	
RACQ	Range of Initial Acquisition	G	
RIFF	Range of Interrogation	G	
RLOCK	Range of Lock-On	G	
RFIRE	Range of Weapon Fire	G	
TDET	Time of Detection	TL or G	Based on seconds after target availability where availability begins once the computer commands the target to rise
TID	Time of Identification	TL	Time interval between Detection and Identification
TENG	Time of Command to Engage	TL	Time interval between Identification and Command to Engage/ Cease Engagement
TACQ	Time of Initial Acquisition	G	Time interval between Detection and Acquisition
TIFF	Time of Interrogation	G	Time interval between Detection and IFF

Table 5 (continued)

TLOCK	Time of Lock-On	G	Time interval between Acquisition and Lock-on
TFIRE	Time of Weapon Fire	G	Time interval between Lock-on and Fire
TTOT	Total Engagement Time	Both	ime interval between Detection and Fire
THAND	Time of Handoff	Both	Time interval between Command to Engage and Weapon Fire

KEY: TL = Team Leader
G = Gunner

Table 6
Sample Descriptive Statistics (N = 18)

VARIABLE	CODE	MEAN	STD DEV	MIN	MAX
AGE	AGE	19.9	2.5	17.0	27.0
NEAR ACUITY	NA	7.5	1.6	6.0	13.0
CONTRAST SENSITIVITY	CS	1.8	0.4	1.2	2.4
DARK FOCUS	DF	1.2	0.8	-0.4	2.6
NEAR POINT FOCUS	NP	8.6	1.9	5.4	11.0
FAR POINT FOCUS	FP	-0.9	0.8	-3.2	0.0
FOCAL RANGE	FR	9.3	2.0	5.8	12.8

KEY: UNITS OF MEASUREMENT

AGE: Years
NEAR ACUITY: Height/width of smallest characters resolvable at 20 feet in n/32 inches (12/32 = 20/20)

CONTRAST SENSITIVITY: Average contrast interval at detection across 5 frequency gratings (min = 1, max = 5)
DARK FOCUS: Diopters
NEAR POINT FOCUS: Diopters
FAR POINT FOCUS: Diopters
FOCAL RANGE: Diopters

NOTE: For vision variables, small values indicate better performance for NA, CS, DF, and FP and large values indicate better performance for NP and FR.

The Stinger Missile System

The Stinger is a man-portable air defense (MANPAD), shoulder-fired, infrared-homing (heat seeking) guided missile system. The weapon requires no control from the gunner after firing. Stinger has an identification friend or foe (IFF) subsystem which aids the team chief in identifying friendly aircraft. The Stinger weapon system consists of four components: the weapon round, IFF subsystem, shipping and storage containers, and transport harness. The Stinger weapon round is made up of a missile round consisting of a Stinger missile within a launch tube mated to a separate gripstock. A battery/coolant unit (BCU) is inserted into the weapon round to provide prelaunch power to the system. All of the components, including the missile, separate gripstock, IFF antenna, and BCU, are necessary to achieve an operational weapon. The weapon is 60 inches long, and with BCU inserted, weighs 34.7 pounds. For IFF simulation capability, an IFF interrogator is connected by cable to the weapon. The Stinger tracking-head trainer (THT) which is a replica of the actual weapon, was used during the conduct of this study. The THT weighs about 40 pounds and simulates all the operational characteristics of the Stinger weapon. The training given to MANPAD teams during this test was performed using the Stinger THT.

Environment

The test was conducted in mid-September, 1986, under clear day conditions. The mean visibility range was 50 miles, and temperatures ranged between 70 and 90 degrees. Windspeed ranged from 0 to 30 miles per hour. The test environment consisted of desert terrain, with no intermediate terrain masking of FW or RW targets. Targets were presented to the south of the weapon position.

Procedures

Teams were alerted 10 seconds prior to target availability by a constant alert message of "Red-Tight". This message established the air defense warning condition as "Red", meaning aircraft imminent and the weapon control status as "Tight", meaning aircraft must be visually identified as "hostile" prior to engaging. Prior to the 10 second alert message, teams were oriented due north, away from the active search sector, in a seated position, which was in defilade to the target area. Upon issuance of the "Red-Tight" alert message, teams manned the weapon position in preparation for the target. After each trial ended, the teams were given a message which informed them that the alert status had changed from "Red" to "White". Teams returned to positions facing away from the target area upon receiving this message. The weapon was temporarily stored on a platform between trial presentations.

The aircraft interrogation process was simulated using an IFF Simulator, modified to emit only an "Unknown" return. This was done to force teams to positively identify each aircraft as "friend" or "hostile". No directional (azimuth orienting) cues were given. All targets appeared within a 90 degree search sector that had to be visually searched without optical aiding to detect each target. The visual search process was allowed to vary among teams. Team chiefs used standard issue 7 x 50 power binoculars for the purpose of visual aircraft identification.

Subject teams were trained in and forced to follow the following target engagement event sequence logic:

1. Both team members visually SEARCH the sector for aircraft.
2. Any team member DETECTS the aircraft and announces the word "Contact" along with a clock azimuth denoting its approach.
3. Gunner INTERROGATES the target (now in his sight reticle) by depressing IFF switch and announces the result.
4. Team Chief visually IDENTIFIES aircraft and announces it as "Hostile" or "Friendly".
5. Gunner ACQUIRES the target in the sight reticle by getting IR tone.

6. Gunner LOCKS-ON to the target using the tone signal generated by the infrared seeker head.

7. Team Chief commands either "ENGAGE" or "CEASE ENGAGMENT".

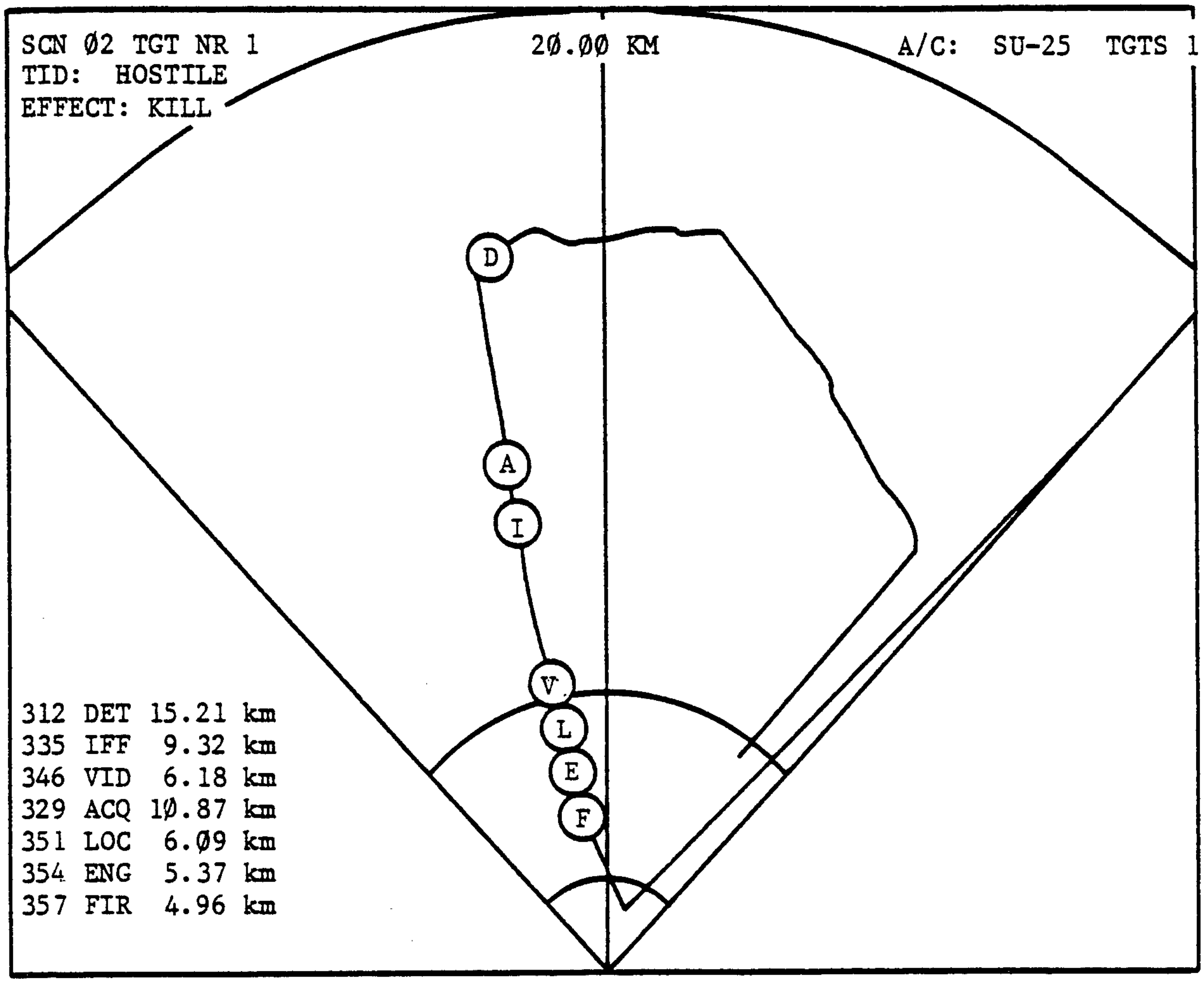
8. Gunner FIRES or BREAKS-OFF from the current target engagement.

The detection, identification and command to engage/cease engagement events were time-coded and logged via manual keystroke entries made by an observer. The interrogate, acquire, lock-on and fire events were time-coded and logged via direct circuit taps on the weapon system. Each event was correlated to the range of the aircraft and the time elapsed after target availability.

Training Feedback

Following each training trial, a feedback screen was presented to the platoon sergeant acting as the training instructor. The time from end-of-trial to presentation of graphic feedback at the weapon averaged three minutes. An ARI research scientist interpreted the feedback screen for the instructor, who in turn, gave a corrective critique to the Stinger team chief and gunner.

An example feedback screen for a fixed-wing scenario is presented in Figure 1. Figure 2 provides an example rotary-wing feedback screen display. These figures were generated from dummy data, but represent the kind of information given as feedback. Information was presented in both tabular and graphic form. The fixed-wing feedback display provided, for each target, event times, ranges, and target model identity. Symbols for each of the sequential events were placed along the flight path to enable team members to judge the relative range of the target at event occurrence. Rotary-wing displays differed in one respect from the fixed-wing feedback displays. Since rotary-wing targets were presented at a constant range, the range values on the display did not vary.

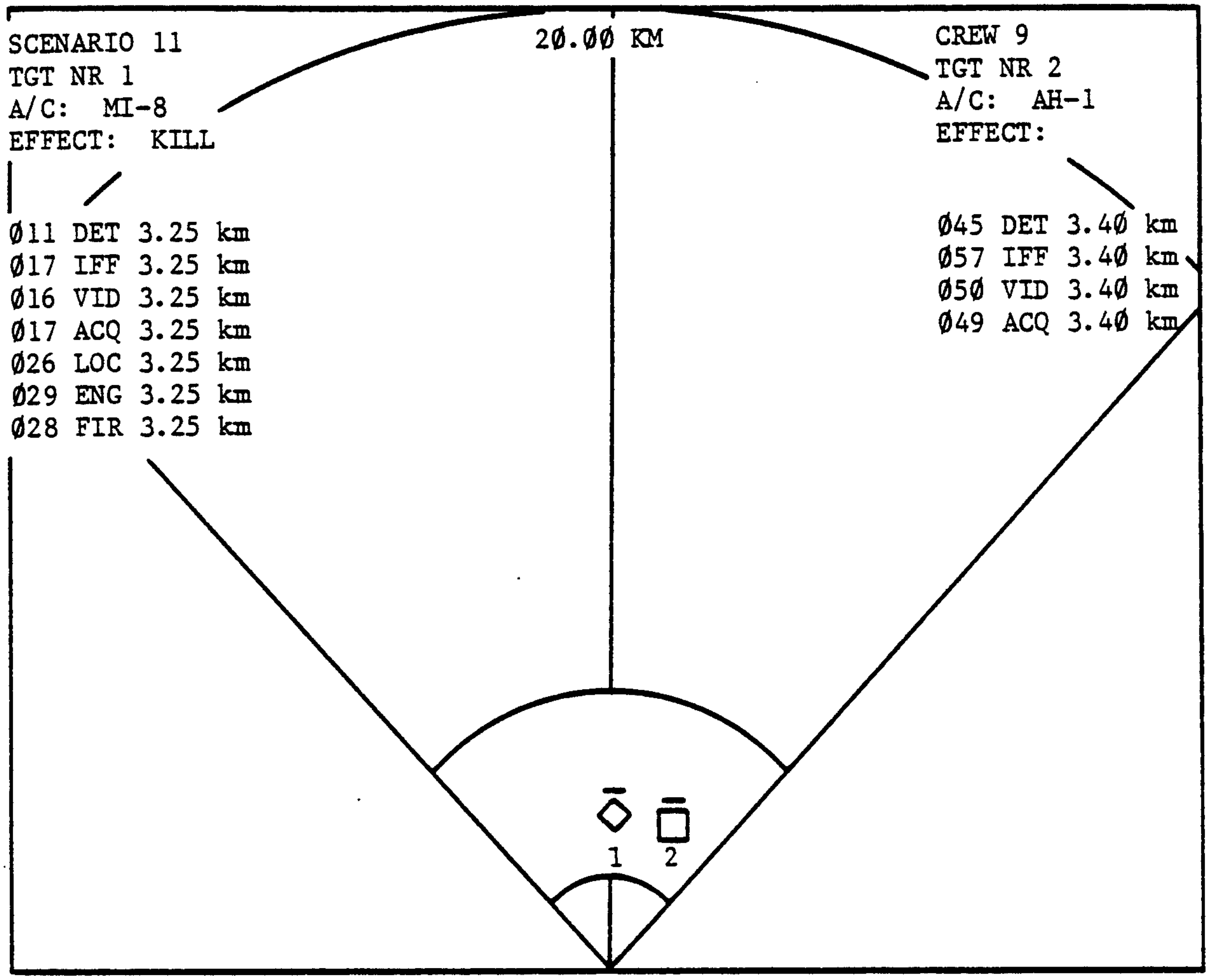


```
SCN 02 TGT NR 1                    20.00 KM                A/C:  SU-25   TGTS 1
TID:  HOSTILE
EFFECT: KILL

312 DET 15.21 km
335 IFF  9.32 km
346 VID  6.18 km
329 ACQ 10.87 km
351 LOC  6.09 km
354 ENG  5.37 km
357 FIR  4.96 km
```

FIGURE 1

FIXED WING SCENARIO FEEDBACK SCREEN



```
SCENARIO 11
TGT NR 1
A/C:  MI-8
EFFECT:  KILL

011 DET 3.25 km
017 IFF 3.25 km
016 VID 3.25 km
017 ACQ 3.25 km
026 LOC 3.25 km
029 ENG 3.25 km
028 FIR 3.25 km
```

```
20.00 KM
```

```
CREW 9
TGT NR 2
A/C:  AH-1
EFFECT:

045 DET 3.40 km
057 IFF 3.40 km
050 VID 3.40 km
049 ACQ 3.40 km
```

FIGURE 2

ROTARY WING SCENARIO FEEDBACK SCREEN

Results

Three categories of data analysis activities are reported: descriptive statistics, correlational statistics, and comparison statistics. The descriptive statistics provide an indication of the average performances across all teams for each experiment. The correlations provide information as to the relationships between team attributes and performance. The comparison statistics were employed to test the hypothesis of improved posttest performance in response to previously presented scenarios. The results of the comparison between pretest and posttest scenario performance will be reported first.

Comparison Tests

The pretest scenarios for the two scenario sets were 11 and 25 (see Table 4). The posttest scenarios for the two sets were 12 and 26. These scenarios represented double, sequential, rotary-wing target presentations. An attempt was made to insure that, across sets, the pretest and posttest scenarios were equivalent for clock azimuth, target intent, and target size. The pretest targets were the large Soviet Mi-8s at 12 o'clock and the small U.S. AH-1 at either 1 o'clock or 11 o'clock respectively. The posttest targets were the large U.S. CH-3 at 12 o'clock, and the small Soviet Mi-28 at either 11 o'clock or 1 o'clock, respectively.

There was a 3 to 5 second delay between "target availability" (when the computer commanded the helicopter to rise) and "line-of-sight" (when the helicopter had risen far enough to be seen from the weapon position). Variability in this delay resulted from variability in terrain, target system, and atmospheric conditions.

The hypothesis being tested was that the duration of timed events subsequent to availability would be shorter for the posttest treatments due to an improvement in performance attributable to the training received. The expected trend was that performance would improve after training, so a one-tailed alpha was chosen and the significance level was set at .10.

Since aircraft intent (friend, foe) differed in the pre-post treatments, only events unrelated to weapon engagement could be meaningfully compared. Target size and order differences also prohibited comparison of engagement (gunner) actions. Therefore, effects for the events of lock-on and fire will not be discussed.

Pre- and post-treatment responses were compared to determine if performance differed. The sign (binomial) test was used to make these comparisons. Table 7 presents the results of these comparisons.

Table 7
Pre- and Post-Treatment Comparisons of Rotary-Wing Event Times

		PRE		POST			SIGN TEST		
VARIABLE	TARG	MEAN	SD	N	MEAN	SD	N	+,-	SIGNIFICANCE
TDET	1st	15.2	1.7	9	10.5	2.1	7	7,0	p<.01
TDET	2nd	45.4	5.3	8	40.0	3.8	7	6,0	p<.05
TID	BOTH	9.4	3.1	9	4.9	0.8	7	7,0	p<.01
TACQ	BOTH	3.8	2.1	8	2.9	1.2	7	5,1	p=.11
TIFF	BOTH	8.6	7.4	7	3.4	3.0	7	4,1	NS
TENG	BOTH	3.6	5.6	6	1.0	0.0	8	2,0	NS
TLOCK	BOTH	9.9	4.4	9	6.3	2.6	7	5,1	p=.11
TFIRE	BOTH	2.2	1.1	9	1.8	1.2	7	4,1	NS
TTOT	BOTH	14.3	4.8	9	9.9	2.3	7	6,1	p<.10
THAND	BOTH	5.0	1.7	8	4.5	1.6	7	3,3	NS
IDCOR	BOTH	.81	.12	9	1.0	.00	7	4,0	p<.10

NOTE: NS = not significant
BOTH = average response across both targets in the scenario

It is apparent from Table 7 that the teams did significantly better during the posttest than they did during the pretest. Targets were detected, acquired and identified earlier; an improvement of about 5 to 7 seconds was observed during the posttest. Almost a 50% improvement was found for the identification event alone. These improvements represent the kind of performance increment desired by the ADA training community. When exposed to multiple aircraft, it is important that the fire units detect and identify each aircraft rapidly so that the hostiles can be picked out and engaged according to the greatest threat.

Table 8 presents a comparison of the pre-post treatments with respect to summary performance measures. Identification accuracy showed improvement during the posttest. During the pretest, 40% of the friendly targets were identified as hostile; none of the hostile targets were misidentified. During the posttest, all targets, friendly and hostile, were identified correctly. During the posttest, no friends were engaged, as opposed to the pretest where 40% of the friends were engaged. These pre-post differences in friendly identifications and friendly engagements were both significant (Cochran's Q=4.0; df=1; 1-tailed p<.05). It is interesting to note that the shorter posttest engagement event times were insufficient to affect a change from pretest to posttest in the percentage of hostiles delivering ordnance.

Table 8
Performance Effectiveness Comparisons

	PRE		POST	
VARIABLE	%	N	%	N
Targets Detected	100	20/20	100	16/16
Targets Identified	100	20/20	100	16/16
Correct Identifications	80	16/20	100	16/16
Incorrect Identifications	20	4/20	0	0/16
Hostiles Correctly Identified	100	10/10	100	8/8
Friends Correctly Identified	60	6/10	100	8/8
Hostiles Engaged	100	10/10	100	8/8
Friends Engaged	40	4/10	0	0/8
Engaged Aircraft Destroyed	93	13/14	100	8/8
Hostile Aircraft Destroyed	90	9/10	100	8/8
Friendly Aircraft Destroyed	40	4/10	0	0/8
Correct Hand-offs	100	20/20	100	16/16
Hostiles Delivering Ordnance	100	10/10	100	8/8

A final pre-post comparison test was conducted to determine if team performance improved after each subsequent target presentation. If a trend existed in the data demonstrating a positive gain as the training progressed, then it could be inferred that learning had taken place. Data from single presentations of rotary-wing targets were reviewed since most of the scenarios began with a single RW target (e.g., scenarios 5, 6, 7, 8, 9, 10, 11, 12, 19, 20, 21, 22, 23, 24, 25, 26). The size of the aircraft was used as a control; large models (CH3, MI8, MI24, MI28) were reviewed separately from the small models (UH1, AH1).

A sign test was performed where an improvement in reaction time over a preceding trial would receive a (+) and a decrement in performance on a subsequent trial would receive a (-). Therefore, each time a team was exposed to a single RW target of the same size (large or small), their responses were recorded in terms of being better or worse than before (ties were excluded). The results for each team for each of the two RW target sizes were pooled at the end to obtain a tally of pluses and minuses. Tallies resulting from the small RW trial comparisons were so low (n=7) that they were pooled with tallies from the large RW trial comparisons (n=38) resulting in a total number of 45 possible comparisons. A one-tailed test was performed on the resulting tally, the alternative hypothesis being that a positive improvement trend would emerge. The event times for RW detection and identification were analyzed. The following formula (Conover, 1980) was used to obtain the critical region.

$$T \geq np + Wr\sqrt{np(1-p)}$$

(n = sample size; p = .5; 1-p = .5; Wr = 1.645 for alpha = .05)

The results of this analysis are summarized in Table 9. There was a trend in the single RW data indicating that performance improved overall as the training progressed. This was especially true for the reduction in identification time after target detection. The improvement trend in performance on the large RW scenarios was much more profound than for the small RW scenarios. These findings add further support to the assertion that RADES can be used to provide effective training.

Table 9
Results of Improvement Trend Tests

VARIABLE	+	-	1-TAILED PROBABILITY
TDET	27	17	.07
TID	28	15	.03

The results reported above relate only to RW engagement performance. More research is required to determine if any performance gain due to RADES training can be found for FW engagements. Later training research using RADES will address this and other relevant issues. However, this pilot program has provided insights in determining what future test requirements and issues should be addressed.

Descriptive and Summary Statistics

Descriptive statistics were compiled across all teams, according to training treatment, for each target. Summary performance measures for each treatment (experiment) and target are provided in Tables 10 to 13. Descriptive statistics are given in Tables 14 to 17. These tables can be found at the end of this section.

Table 10 presents summary statistics for the Single Fixed-Wing test (Experiment 1). Teams detected and identified all FW target aircraft. However, almost a third of the aircraft were incorrectly identified, with the majority of the incorrect identifications being misidentifications of friendly aircraft. Thus, hostile fixed-wing aircraft (i.e., MIG-27s and SU-25s) were more often correctly identified than the friendly aircraft (i.e., A-7s and A-10s). In fact, identification accuracy for friends was slightly above chance performance. Almost all aircraft perceived to be hostile were fired upon, resulting in 100% engaged aircraft destroyed. Two of the hostiles that were correctly identified were not engaged, possibly because of incorrect handoffs, as handoff accuracy was 72%. Friendly fratricide was high at 44%. Seventy-eight percent of the hostiles were prevented from delivering ordnance.

Table 11 provides summary statistics for the Single Rotary-Wing test (Experiment 2). Again, as was the case for fixed-wing aircraft, the teams detected and identified 100 percent of the targets. Friendly RW targets were correctly identified more often than friendly FW aircraft. Only 12 percent of the friendly rotary-wing targets were misidentified, and only 3 percent of the hostiles were incorrectly identified. Again, hostile aircraft were more often correctly identified than friendly aircraft. Stinger teams were better at RW scenarios than FW scenarios in handoffs and identification accuracy, but were virtually ineffective in preventing hostile ordnance release during the RW trials.

Table 12 provides summary statistics for the Double Sequential Rotary-Wing test (Experiment 3). All first targets were detected and identified, with all identifications correct for both hostile and friendly aircraft. This level of accuracy was not sustained for subsequent targets, where identification performance was reduced by 22%. This resulted in a 40% friendly fratricide rate. All second target misidentifications occurred during the pretest scenarios, as posttest identification accuracy was 100%. Handoff accuracy was 100% for both targets. All hostile targets would have delivered ordnance prior to their being destroyed.

Table 13 presents summary statistics for the Simultaneous Double and Triple Rotary-Wing test (Experiment 4). When all of the RW aircraft were presented at the same time, the Stinger teams obviously did not correctly identify the first target entertained with 100 percent accuracy. Literally one-half (overall) of the friendly RW aircraft in the multiple, simultaneous aircraft presentations were incorrectly identified. Only 15 percent (overall) of the hostile aircraft were misidentified.

Friendly rotary-wing identification was about the same in second target engagements as it was in first target engagements. However, on second targets, hostiles were correctly identified 100% of the time instead of 88% of the time. Thus, as friendly correct identifications stabilized, hostile correct identifications appeared to improve in second aircraft engagements. Interestingly, however, hostile target correct identifications declined in third target engagements; Stinger teams dropped 43% from second to third target engagements. Time management appeared to suffer, with the least time given to identification for the third target.

Table 14 presents engagement event range descriptive statistics for Experiment 1, the Single Fixed-Wing test. Engagement event target ranges are in fullscale meters. As shown in this table, targets were frequently fired at beyond the effective range of the Stinger weapon system. At maximum range, several seconds will be consumed by the round flight to aircraft intercept. Thus, some of the ingressing aircraft would have been effectively destroyed, given adequate lock-on and superelevation of the weapon at time of fire; the aircraft would have flown within range once the intercept point was reached. Table 14 also provides the engagement event ranges for hostile and friendly fixed-wing targets.

During Experiment 1, the mean period from detection to fire was 30.2 seconds. This is consistent with prior RADES test results, which place this same average time interval at 30 to 40 seconds. Again, as in prior RADES experiments, the time interval from target detection to target identification runs over half this engagement period (detection to fire) at 19.6 seconds. Thus, the team used about one third of this period for finalizing the engagement process. The time between positive identification (command to engage) and fire is largely controlled by aircraft range, since the gunner must wait to fire until the aircraft is sufficiently close, to avoid a miss.

Table 15 presents engagement efficiency descriptive statistics for Experiment 2, the Single Rotary-Wing test. The mean period from detection to fire was 12 seconds. This is consistent with prior RADES test results, which place this time interval at 10 to 16 seconds. Also, as in prior RADES experiments, the time interval from target detection to target identification runs over half the period between detection and fire at 7.4 seconds. Again, the team used about a third of this total period for finalizing the engagement process. The fact that interrogation times are late and there are many missing cases is indicative of the inexperience of these subjects as compared to previous RADES studies. This finding is replicated in the tables which follow.

Table 16 presents engagement efficiency descriptive statistics for Experiment 3, the Sequential Double Rotary-Wing test. A mean period from detection to fire of 15.3 seconds was found for the first target. This value is also consistent with prior RADES tests, as is the time interval from target detection to target identification (7.5 seconds). Reaction time intervals for the second target were somewhat shorter.

Table 17 presents engagement efficiency descriptive statistics for Experiment 4, the Simultaneous Double and Triple Rotary-Wing tests. For target one, the mean period from detection to fire was 14 seconds. The interval between detection and identification was 5.6 seconds. These results again reflect the overall consistency of responses to RADES targets. Responses to the second target were comparable, but third target responses were faster. It can be seen, however, that only about half of the teams were able to engage the third target, indicating a quickness in responding by the leaders and gunners for those teams. Further, the fact that mean times for acquisition were smaller than those for detection for second and third targets is indicative of the greater speed of some of the teams in completing engagements and addressing new targets. Some gunners were able to obtain acquisition shortly after detection, thereby enabling rapid lock-on and fire if commanded to engage.

In summary, of the total engagement period (availability through fire), the detection event takes about half of the time. The engagement process subsequent to aircraft detection was primarily taken up by the identification task. About 2/3 of the elapsed time between detection and fire involved identification. The last 1/3 of this time interval was taken by gunner response actions to the team leader's command to engage. Air Defense training typically concentrates on these critical aspects of the engagement sequence: aircraft detection, identification, and weapon engagement.

Some general trends emerged as a result of this study. The first is the apparent tendency for these Stinger teams to have a hostile aircraft orientation. Foes were identified correctly more consistently, whereas friends were frequently identified as foes. This finding is supportive of earlier RADES results demonstrating that novices tend to possess a "hostile mind set." Thus, when in doubt, the tendency is to fire. Another trend is the apparent increase in speed of performance as the number of targets increases. For single RW trials, and for first targets, teams seemed to take their time, whereas second and third targets produced much shorter reaction times. This effect may be related to team arousal level.

Table 10
Single Fixed-Wing -- Experiment 1 Summary Statistics

VARIABLE	%	N
Targets Detected	100	18/18
Targets Identified	100	18/18
Correct Identifications	72	13/18
Incorrect	28	5/18
Hostiles Correctly Identified	89	8/9
Friendlies Correctly Identified	56	5/9
Hostiles Engaged	67	6/9
Friends Engaged	44	4/9
Engaged Aircraft Destroyed	100	10/10
Hostile Aircraft Destroyed	67	6/9
Friendly Aircraft Destroyed	44	4/9
Correct Hand-offs	72	13/18
Hostiles Delivering Ordnance	22	2/9

Table 11
Single Rotary-Wing -- Experiment 2 Summary Statistics

VARIABLE	%	N
Targets Detected	100	53/53
Targets Identified	100	53/53
Correct Identifications	92	49/53
Incorrect	8	4/53
Hostiles Correctly Identified	96	27/28
Friendlies Correctly Identified	88	22/25
Hostiles Engaged	96	27/28
Friends Engaged	8	2/25
Engaged Aircraft Destroyed	93	27/29
Hostile Aircraft Destroyed	89	25/28
Friendly Aircraft Destroyed	8	2/25
Correct Hand-offs	100	53/53
Hostiles Delivering Ordnance	96	27/28

Table 12
Sequential Double Rotary-Wing -- Experiment 3 Summary Statistics

	Target 1		Target 2	
VARIABLE	%	N	%	N
Targets Detected	100	18/18	100	18/18
Targets Identified	100	18/18	100	18/18
Correct Identifications	100	18/18	78	14/18
Incorrect	0	0/18	22	4/18
Hostiles Correctly Identified	100	10/10	100	8/8
Friendlies Correctly Identified	100	8/8	60	6/10
Hostiles Engaged	100	10/10	100	8/8
Friends Engaged	0	0/8	40	4/10
Engaged Aircraft Destroyed	90	9/10	100	12/12
Hostile Aircraft Destroyed	90	9/10	100	8/8
Friendly Aircraft Destroyed	0	0/8	40	4/10
Correct Hand-offs	100	18/18	100	18/18
Hostiles Delivering Ordnance	100	18/18	100	8/8

Table 13
Simultaneous Double and Triple Rotary-Wing -- Experiment 4
Summary Statistics

VARIABLE	Target 1		Target 2		Target 3	
	%	N	%	N	%	N
Targets Detected	100	16/16	100	16/16	100	8/8
Targets Identified	100	16/16	100	16/16	100	8/8
Correct Identifications	69	11/16	75	12/16	62	5/8
Incorrect	31	5/16	25	4/16	38	3/8
Hostiles Correctly Ident.	88	7/8	100	9/9	57	4/7
Friendlies Correctly Ident.	50	4/8	43	3/7	100	1/1
Hostiles Engaged	75	6/8	100	9/9	57	4/7
Friends Engaged	38	3/8	14	1/7	0	0/1
Engaged Aircraft Destroyed	78	7/9	100	10/10	100	4/4
Hostile Aircraft Destroyed	63	5/8	100	9/9	57	4/7
Friendly Aircraft Destroyed	38	3/8	14	1/7	0	0/1
Correct Hand-offs	87	14/16	100	16/16	100	7/7
Hostiles Delivering Ordnance	100	8/8	100	9/9	100	7/7

Table 14
Single Fixed-Wing Event Ranges (Meters) --
Experiment 1 Descriptive Statistics

Event	N	Mean	Std Dev	Range	Min	Max
RDET	18	12974	2524	7681	8440	16121
RIFF	13	7860	3909	12950	1594	14544
RID	18	8065	3220	12355	1981	14336
RACQ	17	9093	3196	10957	4414	15371
RENG	11	8538	2505	7155	5123	12278
RLOCK	10	6047	2734	8975	1856	10831
RFIRE	10	5635	3087	8975	1856	10831

	Hostile Targets			Friendly Targets		
Event	N	Mean	Std Dev	N	Mean	Std Dev
RDET	9	13643	2945	9	12305	1963
RIFF	6	6988	4903	7	8607	3018
RID	9	8802	2385	8	7235	3964
RACQ	9	9845	3221	8	8246	3154
RENG	8	8988	2483	2	6738	2284
RLOCK	6	6412	2732	4	5501	3055
RFIRE	6	5835	3276	4	5336	3241

Table 15
Single Rotary-Wing Event Times (Seconds) --
Experiment 2 Descriptive Statistics

Event	N	Mean	Std Dev	Variance	Range	Min	Max
TDET	53	13.62	3.25	10.59	13.0	8.0	21.0
TID	53	7.38	3.51	12.35	16.0	2.0	18.0
TACQ	39	3.30	1.44	2.06	5.0	1.0	6.0
TIFF	36	8.17	9.87	97.46	47.0	1.0	48.0
TENG	21	1.90	3.92	15.39	18.0	1.0	19.0
TLOCK	27	7.33	3.92	15.38	20.0	3.0	23.0
TFIRE	28	2.00	1.90	3.63	10.0	1.0	11.0
TTOT	29	12.00	4.77	22.79	24.0	6.0	30.0
THAND	28	4.86	3.61	13.02	14.0	1.0	15.0

	Hostile Targets			Friendly Targets		
Event	N	Mean	Std Dev	N	Mean	Std Dev
TDET	28	14.61	3.51	25	12.52	2.58
TID	28	5.68	1.79	25	9.28	4.01
TACQ	19	3.11	1.59	20	3.50	1.28
TIFF	18	6.89	7.66	18	9.44	11.77
TENG	15	2.13	3.64	2	1.00	0.00
TLOCK	24	7.29	4.02	3	7.67	3.79
TFIRE	26	2.04	1.97	2	1.50	0.71
TTOT	27	12.04	4.93	2	11.50	2.12
THAND	27	4.96	3.63	1	2.00	0.00

Table 16
Sequential Double Rotary-Wing Event Times (Seconds) --
Experiment 3 Descriptive Statistics

Target 1

Event	N	Mean	Std Dev	Variance	Range	Min	Max
TDET	18	12.67	3.01	9.06	10.0	8.0	18.0
TID	18	7.50	4.03	16.26	16.0	3.0	19.0
TACQ	14	3.64	1.91	3.63	6.0	1.0	7.0
TIFF	15	5.40	6.50	41.97	21.0	1.0	22.0
TENG	7	3.43	5.22	27.29	14.0	1.0	15.0
TLOCK	8	9.25	5.65	31.93	18.0	2.0	20.0
TFIRE	9	2.11	0.78	0.61	2.0	1.0	3.0
TTOT	10	15.30	5.08	25.79	16.0	9.0	25.0
THAND	9	5.56	3.43	11.78	12.0	2.0	14.0

Target 2

Event	N	Mean	Std Dev	Variance	Range	Min	Max
TDET	17	42.47	5.56	30.89	20.0	34.0	54.0
TID	17	6.88	3.45	12.23	11.0	2.0	13.0
TACQ	9	3.22	2.39	5.69	7.0	1.0	8.0
TIFF	11	7.09	6.62	43.89	17.0	1.0	18.0
TENG	10	1.00	0.00	0.00	0.0	1.0	1.0
TLOCK	9	7.33	3.24	10.50	9.0	3.0	12.0
TFIRE	10	2.10	1.73	2.99	5.0	1.0	6.0
TTOT	12	10.33	4.16	17.33	16.0	4.0	20.0
THAND	10	4.60	1.78	3.16	5.0	2.0	7.0

Table 17
Simultaneous Double & Triple Rotary-Wing Event Times (Seconds)
-- Experiment 4 Descriptive Statistics

Target 1

Event	N	Mean	Std Dev	Variance	Range	Min	Max
TDET	16	11.31	2.30	5.30	9.0	9.0	18.0
TID	16	5.56	3.93	15.46	17.0	2.0	19.0
TACQ	11	2.82	1.60	2.56	5.0	1.0	6.0
TIFF	9	3.00	1.94	3.75	6.0	1.0	7.0
TENG	9	1.11	0.33	0.11	1.0	1.0	2.0
TLOCK	9	8.44	5.81	33.78	15.0	2.0	17.0
TFIRE	8	2.50	1.64	2.86	5.0	1.0	6.0
TTOT	9	14.00	5.34	28.50	17.0	8.0	25.0
THAND	7	4.86	1.07	1.14	3.0	4.0	7.0

Target 2

Event	N	Mean	Std Dev	Variance	Range	Min	Max
TDET	16	23.87	6.80	46.25	30.0	12.0	42.0
TID	16	7.50	4.34	18.80	18.0	3.0	21.0
TACQ	1	3.00	0.00	0.00	0.0	3.0	3.0
TIFF	8	8.37	9.93	98.55	28.0	1.0	29.0
TENG	7	1.00	0.00	0.00	0.0	1.0	1.0
TLOCK	8	15.37	7.40	54.84	23.0	2.0	25.0
TFIRE	8	2.62	3.42	11.70	10.0	1.0	11.0
TTOT	8	14.00	7.67	58.86	23.0	1.0	24.0
THAND	7	7.57	6.38	40.62	16.0	1.0	17.0

Target 3

Event	N	Mean	Std Dev	Variance	Range	Min	Max
TDET	8	34.50	8.33	64.43	25.0	25.0	50.0
TID	8	5.25	3.41	11.64	9.0	1.0	10.0
TACQ	1	1.00	0.00	0.00	0.0	1.0	1.0
TIFF	3	5.33	4.51	20.33	9.0	1.0	10.0
TENG	2	1.50	0.71	0.50	1.0	1.0	2.0
TLOCK	4	6.50	2.38	5.67	5.0	5.0	10.0
TFIRE	4	1.75	0.96	0.92	2.0	1.0	3.0
TTOT	4	7.50	3.32	11.00	8.0	4.0	12.0
THAND	3	6.00	3.46	12.00	6.0	4.0	10.0

Correlational Analyses

Table 18 provides those correlations between subject attributes and dependent variables which exceeded the .10 level of significance. Spearman (non-parametric) correlation coefficients were computed between average team responses for FW and RW (first targets) and the team attributes. It was assumed that those variables controlled by the team leader (such as command to engage) would be irrelevant for the gunner, and those variables controlled by the gunner (such as lock-on) would be irrelevant for the team leader. Only relevant relationships are presented in Table 18.

Although a few of the correlations are conflicting, one general conclusion that can be drawn from Table 18 is that the vision of the team members played a substantial role in accounting for engagement performance. Another general observation is that the gunner's visual capabilities contributed more to the outcomes than those of the team leader.

The team leader's contrast sensitivity made a postitive contribution to FW performance, and his dark focus made a positive contribution to RW performance. The flexibility of the leader's visual system (NP, FP, FR) negatively affected FW and RW performance while the gunner's visual flexibility positively affected FW and RW performance. Further, the gunner's acuity, contrast sensitivity, and dark focus played a role in RW performance.

These results are consistent with past RADES tests (SAIC, 1985) as well as other human factors studies. Visual acuity has emerged frequently as a predictor of aircraft target detection and recognition performance (Johnston, 1967; Monaco & Hamilton, 1984), as has contrast sensitivity (Ginsburg & Easterly, 1983; Ginsburg, 1984). The dark focus of accommodation has been a prominent factor in visual task performance (Owens, 1984; Roscoe, 1985; Norman & Ehrlich, 1986). Further, the flexibility of the visual system has been shown on numerous occasions to predict visual task performance (Roscoe, 1979; Norman & Ehrlich, 1986). Therefore, it is reassuring to find that these vision variables were consistently correlated with performance in RADES. These relationships are supportive of earlier RADES findings as well (Barber, 1987).

Table 18
Spearman Correlations Between Team Attributes and Fixed-Wing Ranges and Single, Rotary-Wing Times (p<.10)

	Team Leader						
FW EVENT	AGE	NA	CS	DF	NP	FP	FR
RDET	-.58						
RID					-.56	.85	
RENG	-.69		-.77		-.51	.61	-.57
RW EVENT	AGE	NA	CS	DF	NP	FP	FR
TDET				.61			
TENG	.66						
TTOT					.63	-.51	.49

	Gunner						
FW EVENT	AGE	NA	CS	DF	NP	FP	FR
RDET		.60					
RLOCK					.74		.74
RFIRE		-.55			.77		.74
RW EVENT	AGE	NA	CS	DF	NP	FP	FR
TDET		.74					
TACQ				.65		.60	-.52
TIFF		.52		-.61			-.57
TLOCK	.67				-.58	.52	
TTOT			.44	.60			

Conclusions

This study has shown that RADES can train Forward Area Air Defense soldiers. However, the test was somewhat limited in its scope since only RW training improvements were analyzed. Training effects using FW aircraft must also be investigated. Upcoming training analyses will provide more definitive training effectiveness data.

Some general inferences can be made from the descriptive statistics. Of the total engagement period, the detection event uses up about half of the time. The identification process takes about two thirds of the engagement time subsequent to detection, and the fire sequence takes the remaining third of that time. Thus, improvements in FAAD effectiveness and efficiency may be found in selecting personnel with superior vision. Further, providing identification information to the team, either over the command net or via some optical or imaging device, may help. Additionally, adequate training and practice in a field environment such as RADES may serve to improve teamwork and individual skills. Engagement training with both friendly and hostile aircraft is important.

It was also observed in this test and numerous prior tests (Barber,1987; Drewfs, et. al., in press) that air defense soldiers appear to respond quicker and are more correct in identifying hostiles than friends. This was attributed to the tendency for teams (especially novices) to adopt a hostile set, and thus have a proclivity to fire when in doubt.

The differences exhibited in this study between single, sequential and simultaneous rotary-wing target engagement efficiency and effectiveness are also noteworthy. The presence of subsequent and multiple RW aircraft seemed to reduce reaction time, possibly because of an increase in arousal level of the soldiers. This often resulted in hasty identifications that were incorrect. The workload level would appear to drive the speed of team responses.

ARI investigators also noted that during feedback sessions in this study, soldiers related that certain detailed features they were trained to look for in visual aircraft identifications were absent from the targets. Soldiers stated that this caused them to be initially misled, and to engage friendly aircraft such as the A-10 and CH-3. In addition, they stated that this caused them to misidentify certain hostile targets as friendly. It is recommended, therefore, that such features as electronic countermeasures pods, covers, and parts not be taught as critical features for visual aircraft identification. Aircraft may not always employ these features.

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