Multiplayer Simulator Based Training for Air Combat

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ABSTRACT

Emerging simulation technologies provide new opportunities for training mission tasks and skills which have not been previously trained in simulators. Research is necessary to identify the tasks where additional training would most benefit mission ready pilots and air weapons controllers and which of these tasks represent training opportunities for networked simulators. Armstrong Laboratory, Aircrew Training Research Division has recently developed a SIMNET compatible network of F-15 cockpits with visual systems, an air weapons controller station, manned and digital threats, and an exercise control station. An evaluation of this system was conducted in which 23 F-15 pilots 13 air weapons controllers participated in simulated air combat exercises. Each team of lead pilot, wingman, and controller flew several offensive and defensive counter air missions against a force of up to six aircraft, anti-aircraft artillery, and surface to air missiles. Participants were asked to rate their interest in receiving additional training on each of 36 mission areas. After participating in the simulated air combat exercises, participants rated the value of the training received in the simulator system and the training currently received in their units for each of these mission areas. Data presented identifies, a) tasks which are of particular interest to aircrews, b) which tasks were better trained in the simulation system than in current unit training, and c) changes in pilot performance in simulated air combat related to levels of fighter experience.

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MULTIPLAYER SIMULATOR BASED TRAINING FOR AIR COMBAT

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INTRODUCTION

Background

Air combat requires a unique combination of perceptual, procedural, psychomotor, and cognitive skills. Dion and Bardeen (1990) point out that many existing ground-based trainers emphasize procedural and psychomotor skills by taking a part-task (PTT) approach. While the necessity of such training is unquestioned, Dion and Bardeen assert that, "Limited single-ship PTTs cannot provide multiship and integrative / multitask pilot experiences for team coordination skills,..." (p.467). Vraa (1990) further asserts that, "...the very best combat training flight environments, such as Red Flag, are necessarily constrained by factors relating to peacetime safety rules, resource availability, and funds,..." (p.459). These authors go on to state that multiplayer, air combat simulation against intelligent and responsive forces would fill in important increasing combat readiness. The emphasis of such training would be on cognitive and team skills such as mission planning, communication, tactics, attention management, decision making, and situational awareness.

Dion and Bardeen describe the components of such a training system and Vraa describes the characteristics of simulated opposing forces. The proposed training system would consist of 2-4 fighter cockpits integrated into a common battle space with manned or computer controlled threats. All appropriate systems would interact among players such as radar, weapons, and countermeasures. Houck, Thomas, and Bell (1989) conducted a series of simulated air combat exercises using the simulator complex at McDonnell Aircraft Company. While these simulators were designed for engineering development, it was possible to reconfigure the system for multiplayer air combat training as Dion and Bardeen or Vraa propose. Pilots and air weapons controllers found that using the multiplayer simulation system provided effective training for:

a) Individual skills which can only be practiced infrequently such as radar sorting against multiple bogeys, and

b) Skills which require interaction with other players such as maintaining mutual support and working with an air weapons controller.

While the exercises conducted at McDonnell Aircraft Company demonstrated the value of multiplayer, simulator-based training for air combat, the simulation facility at McDonnell Aircraft was designed for engineering development and uses very high fidelity cockpits and mainframe computer technology. The Multiship Research and Development program (MULTIRAD) was initiated at the Aircrew Training Research Division in the Spring of 1991 to create a SIMNET compatible system of networked simulators for air combat training. The objective of MULTIRAD development was to integrate new and existing devices into a system which would provide high fidelity training for limited components of the F-15 air combat mission. The system would then be evaluated in a series of simulated air combat exercises known as the Training Requirements Utility Evaluation (TRUE). In the TRUE, teams of two F-15 pilots and an air weapons controller would either defend an air base against an attack or would escort a flight of F-16s attacking the air base.

Objectives

TRUE was conducted as an engineering evaluation of the MULTIRAD simulation system. In addition to engineering information, data were collected to identify mission tasks and skills which can be effectively trained using multiplayer simulation. Further, pilot performance in the simulated combat exercises was analyzed to identify discriminators of mission success related to pilot level of experience.

RESEARCH METHODS

MULTIRAD Simulation System

MULTIRAD is a system of networked simulators designed to support air combat training which incorporates many of the features proposed by Vraa (1990) and by Dion and Bardeen (1990). MULTIRAD consists of two F-15C cockpits installed in wide field-of-view visual display systems integrated onto a SIMNET compatible network with:

a) Air Weapons Controller Station

b) Two (2) F-16 simulators configured to participate in TRUE exercises as Su-27 interceptors

c) Automated Threat System

d) Exercise Control and Video Recording System

e) Independent Video Debriefing System

The layout of this system is shown in Figure 1. The simulators within MULTIRAD are limited fidelity systems in that many aircraft capabilities such as take-offs, refueling, emergency procedures, or landing are not simulated. High fidelity models, however, are used for functions critical to air combat. These functions include aircraft aerodynamics and performance, radars, missiles, and the effects of jamming and countermeasures. Platt and Crane (1993) present a detailed description of MULTIRAD.

TRUE Exercises

TRUE was conducted as a series of air combat training exercises similar to the exercises described by Houck et al. (1989). Three or four teams of lead and wing F-15 pilots plus an air weapons controller participated in four, week long exercises. During each of these weeks, teams flew seven, one-hour simulator sessions. During each session, teams flew three or four setups of either a Defensive (DCA) or Offensive (OCA) Counter-Air mission. On DCA missions, the team defended their home airbase against an attack from two MiG-27 fighter-bombers escorted by four Su-27 fighters (two manned and two computer generated). On OCA missions, the F-15s escorted a flight of four computer-generated F-16s attacking the air base which was defended by six Su-27 fighters, four computer-generated and two manned. Each DCA or OCA setup was initiated with the aircraft at 20,000' separated by 80 nautical miles. Computer-generated enemy force tactics were preprogrammed and the manned players

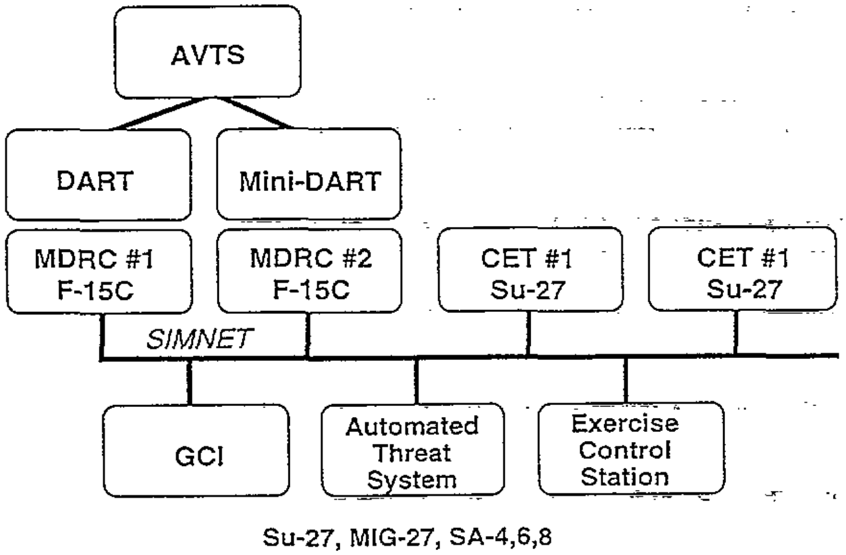

Figure 1. Multiship Research and Development (MULTIRAD) Network

followed a script during the early part of each engagement. There were six variations of enemy tactics for the OCA mission and seven for the DCA mission. In addition, the manned players were free to deviate from the script as circumstances demanded and the computer generated aircraft were programmed to defend themselves when attacked. Figures 2 and 3 illustrate two variations of the DCA and OCA missions. F-15 pilots and controllers were not shown the enemy force plans nor were they informed about which variation would be seen on any setup. Variations were selected at random with the provision that no variation was repeated within a given simulator session.

At the beginning of each week, pilots and controllers were briefed about the TRUE objectives and procedures. Participants then filled out questionnaires listing 30 air combat mission tasks and skills and were asked to rate the desirability of receiving additional training on

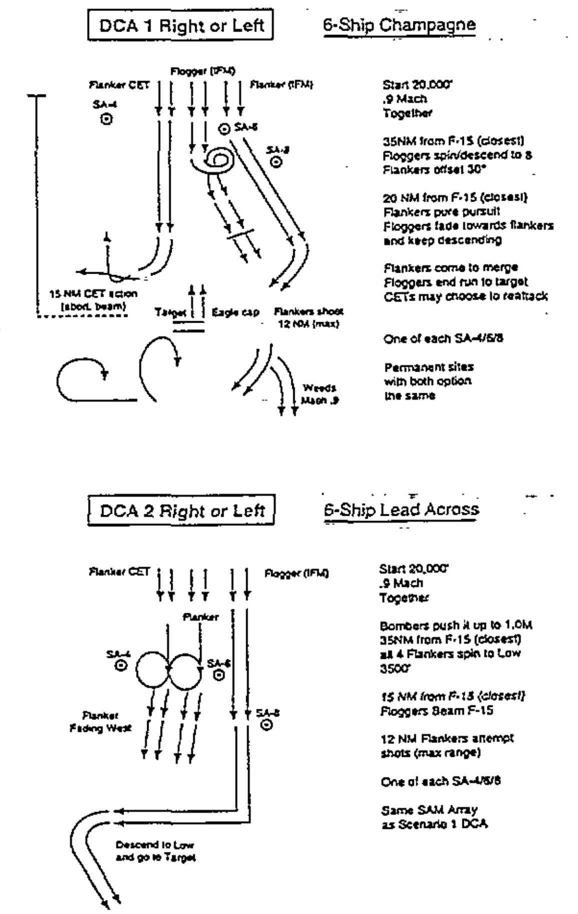

Figure 2. Two Variations of TRUE Defensive Counter Air (DCA) Mission

each. After a familiarization flight, teams flew three DCA and three OCA simulator sessions with three or four setups per session. Before each session, teams planned their missions

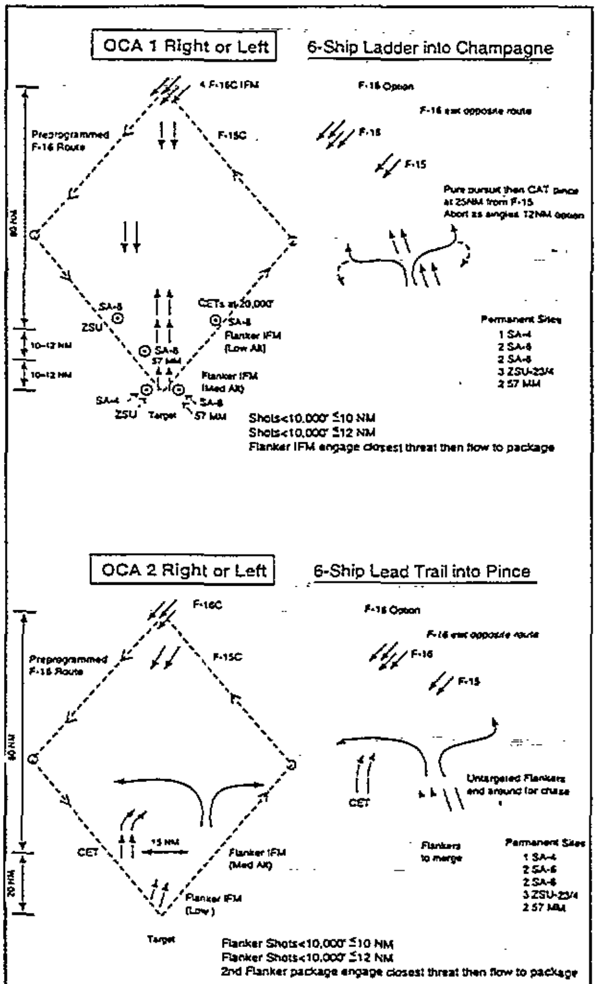

Figure 3. Two Variations of TRUE Offensive Counter Air (OCA) Mission

including call sign assignment, lookout responsibilities, and plans for attack, mutual support, and re-attack. Each engagement was video taped from the exercise control console using three, computer-controlled recorders. Each F-15 cockpit's front panel including the radar, radar warning, and armament control displays was recorded along with the overhead view of the engagement from the control console plus all audio communications and warnings. At the end of the simulator session, teams took the tapes to an independent debriefing room which contained facilities for synchronized playback of the tapes. After debrief, each team's lead pilot completed a questionnaire describing any difficulties they experienced during the missions and lessons learned for the next simulator session. Participant comments and critiques were also solicited during daily meetings with all pilots and controllers. During some TRUE weeks, pilots flew one vs one engagements between the two F-15 cockpits. The results of these engagements are described in Crane (1993). After all simulator sessions had been completed, participants filled out a final questionnaire. On this questionnaire, participants rated the quality of training received in their current unit training program and from MULTIRAD *for each of 30 tasks and skills.*

TRUE Participants

Twenty-three, USAF, F-15 pilots and 13 air weapons controllers participated in TRUE exercises. In this paper, only the results from the pilots will be discussed. Pilot experience levels ranged from 300 to 2500 total flying hours with a median of 1400 total hours and 675 F-15 hours. The distribution of total flight hours of TRUE pilots by unit qualification is shown on Figure 4.

RESULTS

Interest in Additional Training

Pilots rated their interest in receiving additional training on each of 30 tasks using a scale from 1=additional training is not desirable to 5=additional training is extremely desirable. Mean ratings are presented in Figure 5. The 30 tasks on the figure are coded:

TACTICAL FRM	Tactical formation
VISUAL LOW	Visual low level flight
SEPARATION	Separation tactics
VISUAL ID	Visual identification of target aircraft
LOW ALT TAC.	Low altitude tactics
DEBRIEFING	*Mission debriefing*
EGRESS TAC.	Egress tactics
INTRAFLT COM	Flight communication
TWO SHIP TAC	Two-ship tactics
COM JAMMING	Communication jamming
TEWS	TEWS assessment
INTERCEPT	Tactical intercept
MISSILE	Missile employment
ECM	Employ ECM/ECCM
AI RESPONSE	Reaction to airborne interceptors
MUTUAL SUPT	Mutual support
WEATHER	All weather employment
CHAFF	Employ chaff/flares

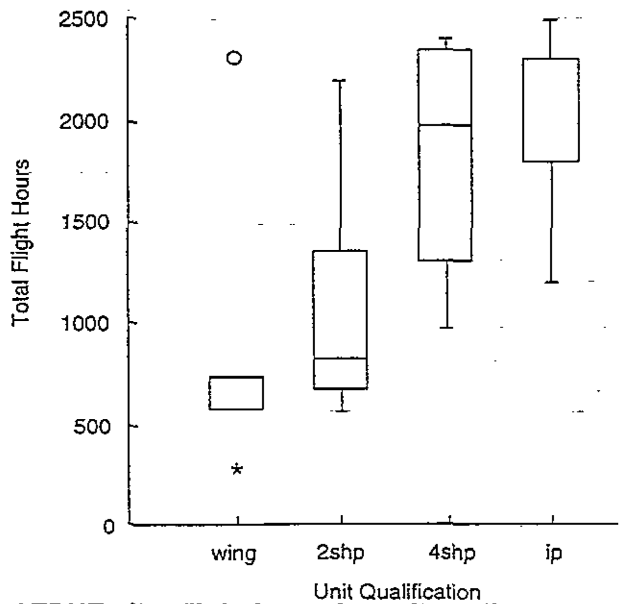

Figure 4. Distribution of TRUE pilot flight hours by unit qualification level (wing = mission ready wingman, 2shp = two-ship flight lead, 4shp = four-ship flight lead, IP = Instructor Pilot)

VISUAL LOOK	*Visual lookout*
EID	Electronic identification of target aircraft
TACTICS/PLAN	Tactics/mission planning and briefing
ESCORT TACTICS	Escort tactics
RADAR LOOK	Radar lookout
WORK W/ GCI	Work with AWACS/GCI
SAM DEFENSE	Reaction to surface-to-air missiles (SAMs)
RADAR SORT	Radar employment /sorting
BVR	Beyond visual range employment
ALL ASPECT D	All aspect defense
DACT	Dissimilar air combat training
FOUR+ BOGEYS	*Multibogey, four or more*

The five tasks with the lowest interest ratings are primarily visual tasks. The tasks with the highest rated interest in receiving additional training are tasks which can usually be practiced only in large exercises or cannot be practiced except in simulation, e.g. defense against SAMs. This result is in agreement with Houck et al. (1989) who found that pilots were most interested in receiving additional training for tasks which are least frequently practiced in the aircraft. Interest is low for tasks such as tactical formation or separation tactics which are practiced on all air-to-air sorties.

Value of MULTIRAD and Current Unit Training

Using the scale of 1=unacceptable to 5=excellent, pilots rated the value of their current unit training and MULTIRAD training for

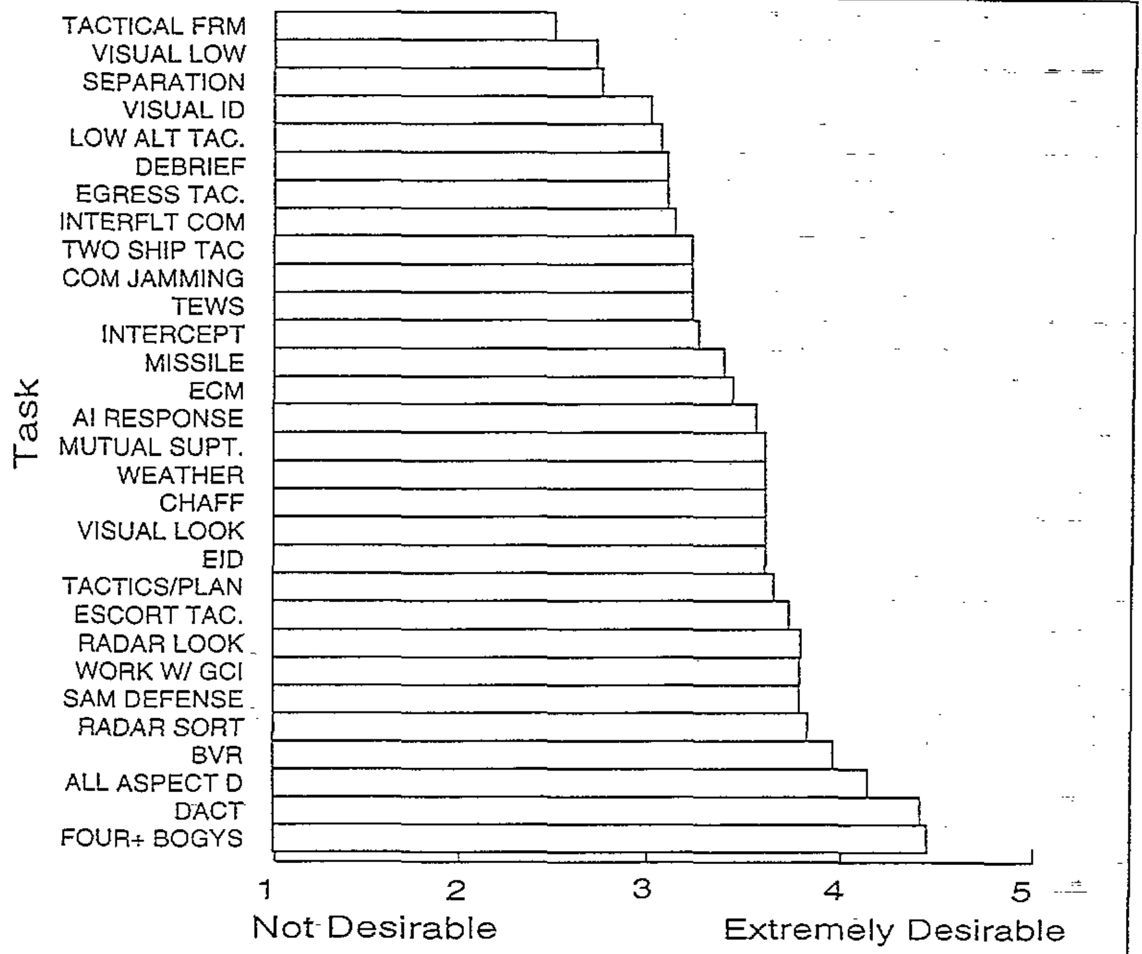

Figure 5. Pilot ratings of interest in receiving additional training for 30 air combat tasks

each of the 30 tasks. The lowest and highest rated tasks for unit and MULTIRAD training are:

	Current Unit	MULTIRAD
Lowest rated tasks	SAM defense	Visual id
	Com jamming	Tactical Form.
	ECM/ECCM	Com jamming
	Work w/ GCI	Visual lookout
	Four+ bogeys	Visual low alt.
Highest rated tasks	Visual lookout	Radar lookout
	Tactics /planning	*Work w/GCI*
	Mutual sup.	Radar sorting
	Tactical Form.	BVR employ.
	Radar lookout	Four+ bogeys

While some tasks, notably radar lookout, were rated highly for both MULTIRAD and current unit training, more tasks were given high ratings for one training environment and low ratings for the other. For example, visual lookout and tactical formation were the lowest rated tasks for MULTIRAD but among the *highest rated tasks* for current unit training. Likewise, work with GCI controllers and engagements against four or more bogeys were among the lowest rated tasks for current unit training and among the highest rated tasks for MULTIRAD. The differences between the mean *ratings for unit and MULTIRAD training* are plotted on Figure 6. Negative numbers indicate that unit training was rated higher than MULTIRAD training. Tasks with the highest ratings for additional training are printed in UPPERCASE type. Tasks which were rated

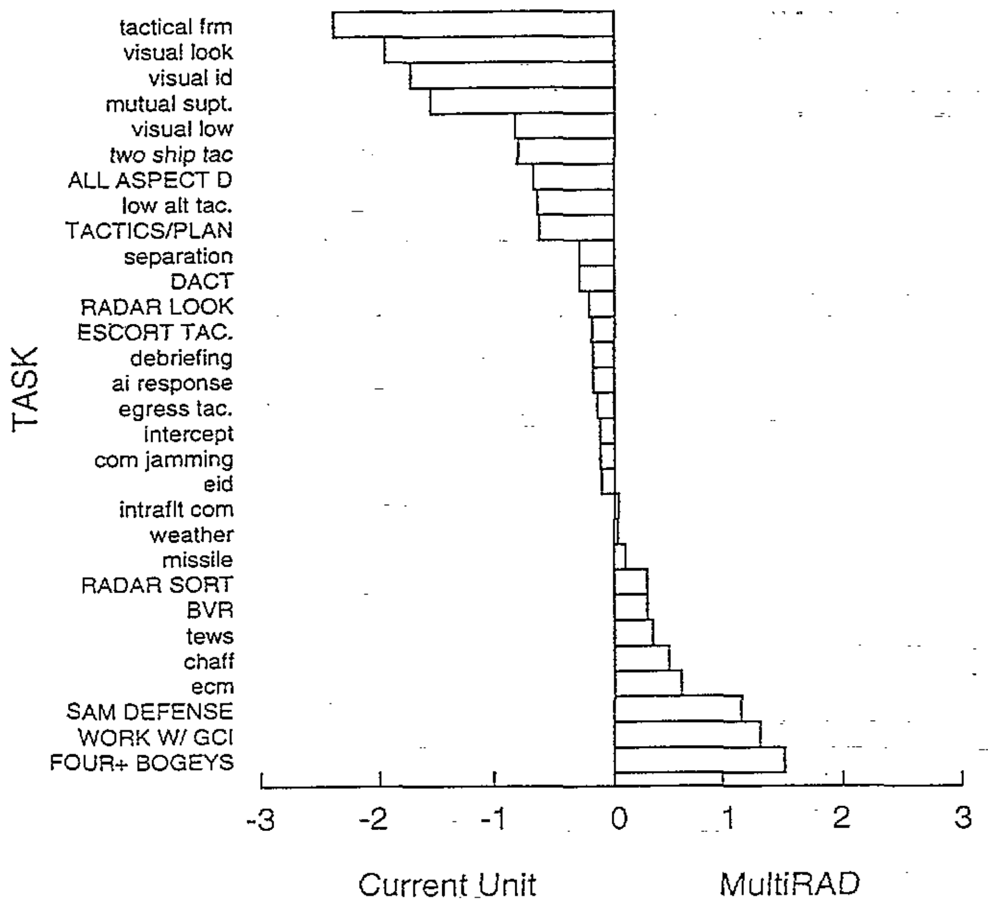

Figure 6. Differences between pilot ratings of training effectiveness for MULTIRAD and current unit training for 30 tasks; tasks for which there is high interest in receiving additional training are listed in UPPERCASE type

much higher in the current unit than in MULTIRAD are primarily visual. These tasks were also among the lowest rated tasks for interest in receiving additional training. Tasks which were rated higher in MULTIRAD than in the current unit are tasks which are not frequently practiced outside of large scale exercises. Also, tasks rated higher for MULTIRAD training were among the highest rated tasks for interest in receiving additional training. This finding is also inagreement with Houck et al. (1989) who reported that pilots rated multiplayer simulator based training higher than unit training for tasks which cannot be practiced in aircraft due to safety, cost, and security restrictions.

Pilot Comments

Pilot comments and critiques primarily fell into three categories: F-15 cockpit operations, simulation of opposing forces, and visual display problems. These comments were used to correct MULTIRAD deficiencies after each TRUE exercise (see Platt and Crane, 1993). Problems with the visual display systems, however, could not be corrected during TRUE. These problems are described in detail by Crane (1993). In brief, the pilots' major criticism was that aircraft were difficult to detect beyond 2 - 4 nautical miles and aircraft aspect or closure could not be determined beyond 0.5 - 1 nautical mile.

Mission Performance

A comparison of mission performance relative to experience levels was performed to determine what areas of mission success could be measured. Fighter pilot performance levels were extracted from previously video taped engagements. A total of over 267 OCA/DCA engagements were flown among the twenty-three pilots. Experienced versus inexperienced levels, rated by flight hours, were discerned as shown in Table 1.

TABLE 1

Inexperienced (Hours)	Experienced (Hours)
MR Wingman = 70 - 500	4-Shp Flt Ld = 600 - 1,000
2-Shp Flt Ld = 300 - 1,000	IP = 700 +

Data points collected included experience with live fire missile shots, experience in live mission exercises, number of various missile and gun shots taken during OCA and DCA scenarios, number of kills and misses, and mission success or failure. Week one through four data examined the F-15 team pilots flying against a full array of threats. The composite threat force on DCA's was 2 (F-15s) vs. 6 (MiGs) plus 3 SAM sites and on OCA's 2 (F-15s) + 4 (F-16 strike package) vs. 6 (MiGs) plus 3 SAM sites. Kill ratio involves two discriminators of mission success, average kills per setup and the number of times the pilot gets killed or morted. Kill ratio/exchange ratio can be examined for analysis of mission success. Most all engagements had the experienced pilots leading the formation and planning/directing the tactics. The exchange ratios were plotted and compared for the experienced and the inexperienced pilot as shown in Figure 7. The discriminator, average kills per setup, examined both OCA and DCA mission scenarios. Overall the complexity of the OCA scenario resulted in the inexperienced pilot to have large fluctuations of kills, however, this type of pilot did show improvement. The expert pilots performance improved more linearly. The DCA scenarios were not as complex, involving only combat air patrol and defensive lane protection. Therefore, results show an increase in kills for inexperienced pilots. Repeated setups for high time pilots showed no marked change. The other facet discriminator, mortality, examined the survival rate of the F-15 pilots. In the OCA missions the results for experienced pilots indicated a higher survival rate initially, however, since the experienced pilot is also the leader and responsible for wingman and strike package this could explain the higher mortality rate with increased setups. The complexity of the OCA for lead involves situational awareness and a host of other factors which are beyond the discussion of this paper. The survival of the wingman during OCAs show an increase mortality rate and then leveling out. This would seem to indicate a rapid learning curve for inexperienced pilots using such a training system. Again, since DCA missions are somewhat less complicated a significant learning curve is predominate in both categories of pilots. The ability to rapidly reset the engagements and learn from mistakes caused a faster learning curve than can be currently trained in actual aircraft. Experienced pilots continued to improve but at a more linear rate. This could be attributed to adaptation and refinement of leads tactical game plan as the scenarios progressed.

DISCUSSION

TRUE was conducted as an engineering test of the MULTIRAD system. However, TRUE also provided the opportunity to gather

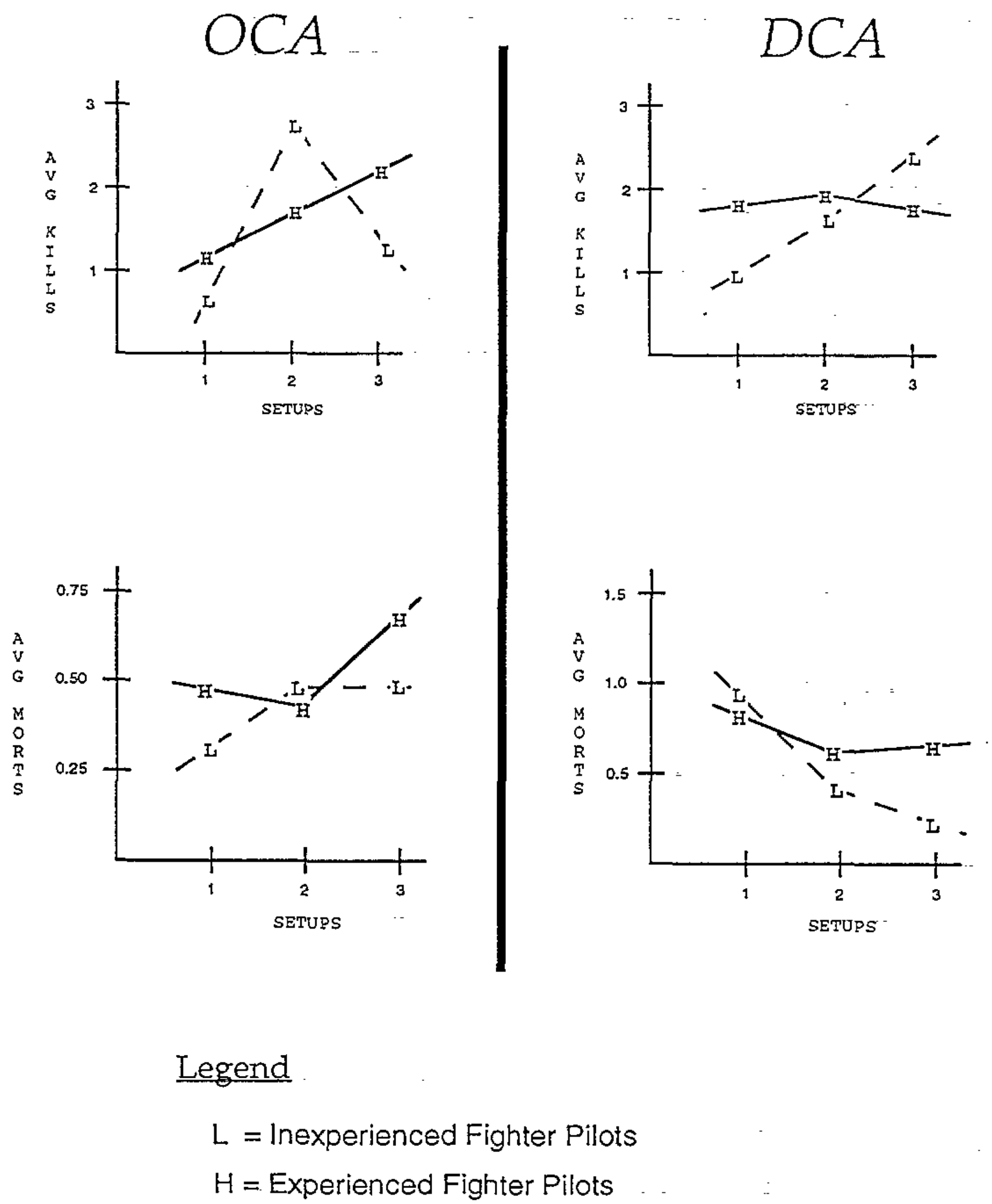

Figure 7. OCA and DCA Kill Ratio versus Experience / Inexperience

behavioral data on training interests and the potential applications of mutiship, simulator-based training for air combat. Overall, the results of TRUE are in agreement with the findings of Houck et al (1989). Although the engineering development simulator system used by Houck et al. at McDonnell Aircraft had more capability than the present MULTIRAD system, TRUE pilots rated simulator training higher than current unit training for a similar list of tasks. These include tasks which can be performed single-ship but are infrequently practiced such as radar sorting against multiple targets. The high rated tasks also include skills which can only be practiced within the context of a team. These tasks include work with a GCI controller and operations against four or more bogeys.

Dion and Bardeen (1990) predict that the major benefit of multiplayer combat training will be the development of team skills. These benefits will come from, "training situations in which the team learns to develop adaptive teamwork skills required in real time for uncertain problems, and an expanded repertoire of team experiences," (p.468). It is unclear, however, whether the benefits of multiplayer simulation come from development of team skills or from the development of individual skills at tasks which can only be practiced within a team context. Crane (1992) predicts that training will be of most benefit for skills which pilots have had the least opportunity to practice. This prediction is based on cognitive models of expertise which assert that a journeyman lacks the expert's extensive knowledge base and is unable to quickly recognize the significant elements within a mission and to select an appropriate response. Simulator based training can provide the foundations for building an expert's knowledge base. Since the tasks in TRUE which were highly rated for MULTIRAD training are both team tasks and infrequently practiced, no conclusion can be drawn regarding Dion and Bardeen's prediction that the benefit of multiplayer simulation will be development of team skills.

Low time fighter pilots certainly benefit from a multiplayer simulation. Mission success criteria depends on pilot performance. Certainly part of this performance is the pilots ability to maintain a high kill ratio level. It seems that this is a good gauge or metric when determining his abilities in combat. It is so important that many fighter squadrons implement a TOP GUN program to track this performance. The discriminators which make up kill ratio, kills versus mortality, certainly indicate that inexperienced pilots will gain more, i.e. have a much more accelerated learning curve, when exposed to near realistic training scenarios over a repetitive period of time. Many other factors also influence mission success; situational awareness, weapons employment ability to name a few. All of these factors comprise the kill ratio metric. Simulation plays a key role for the low time pilot. It is important to them to be exposed to all the pitfalls of flying in combat. By doing so you increase the knowledge base at a more rapid rate utilizing those precious few training sorties for items that cannot be trained in the simulator. The results prove that a high fidelity multiplayer simulation system improves fighter skills.

CONCLUSIONS

The results of TRUE support the contention that multiplayer simulator based training is a valuable training medium for increasing wartime readiness especially for less experienced pilots. Multiplayer simulation is best suited for continuation training as an adjunct to existing unit training. Current training practices are best suited for training many of the tasks required of air combat pilots. Training in simulator systems similar to MULTIRAD is best suited for training tasks which cannot be practiced in aircraft due to cost, safety, and security restrictions.

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