AFRL-HE-AZ-TR-2000-0111

UNITED STATES AIR FORCE RESEARCH LABORATORY

USING DISTRIBUTED MISSION TRAINING TO AUGMENT FLIGHT LEAD UPGRADE TRAINING

Peter Crane

Air Force Research Laboratory
Warfighter Training Research Division
6030 South Kent Street
Mesa, AZ 85212-6061

Robert Robbins

L3 Comm, Link Simulation & Training Division
Air Force Research Laboratory
6030 South Kent Street
Mesa, AZ 85212-6061

Winston Bennett, Jr.

Air Force Research Laboratory
Warfighter Training Research Division
6030 South Kent Street
Mesa, AZ 85212-6061

JUNE 2001

AIR FORCE RESEARCH LABORATORY
HUMAN EFFECTIVENESS DIRECTORATE
Warfighter Training Research Division
6030 South Kent Street
Mesa AZ 85212-6061

NOTICES

Publication of this report does not constitute approval or disapproval of the ideas or findings. It is published in the interest of STINFO exchange.

Using Government drawings, specifications, or other data included in this document for any purpose other than Government-related procurement does not in any way obligate the US Government. The fact that the Government formulated or supplied the drawings, specifications, or other data, does not license the holder or any other person or corporation, or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

PETER CRANE
Project Scientist

DEE H. ANDREWS
Technical Advisor

JERALD L. STRAW, Colonel, USAF
Chief, Warfighter Training Research Division

Copies of this report may be requested from:

Defense Technical Information Center
8725 John J. Kingman Road, Suite 0944
Ft. Belvoir, Virginia 22060-6218

http://stinet.dtic.mil

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
JUN 2001	Final	JUN 1999 to FEB 2000

4. TITLE AND SUBTITLE

Using Distributed Mission Training to Augment
Flight Lead Upgrade Training

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
63227F

6. AUTHOR(S)

Peter Crane
Robert Robbins
Winston Bennett Jr

5d. PROJECT NUMBER
2743

5e. TASK NUMBER
B2

5f. WORK UNIT NUMBER
03

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Training Research Div
6030 South Kent Street
Mesa AZ 85212-6061

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Training Research Div
6030 South Kent Street
Mesa AZ 85212-6061

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-HE-AZ-TR-2000-0111

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT Previous research on Distributed Mission Training (DMT) shows that pilots and Airborne Warning and Control System (AWACS) weapons directors rate DMT as highly effective for training multiship, multibogey air combat. DMT exercises were also used as opportunities for pilots participating in Flight Lead Upgrade (FLUG) training to gain experience in planning, briefing, leading, and debriefing 4-ship missions in an intensive air-to-air threat environment. We describe a 4-phase research program at the Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA) in Apr 99 to assess the effectiveness of using DMT to augment FLUG training. We reviewed training records at one F-16 base to identify 4-ship FLUG missions that would benefit most from DMT experience and establish baseline rates for sorties repeated due to noneffective upgrading pilot proficiency. A 5-day DMT-FLUG protocol was developed targeting these missions. DMT-FLUG training exercises were conducted over one year. During these exercises, upgrading pilots led several missions of increasing complexity using the AFRL 4-ship DMT testbed in Mesa AZ with AWACS weapons controllers from AFRL's research facility at Brooks AFB TX. We assessed transfer to aircraft training through review of training records and interviews with both upgrading pilots and their instructors. Eight out of 12 upgrading pilots participating in DMT-FLUG successfully completed the program without any repeated missions, one pilot repeated one mission, two transferred out of fighters, and one pilot was still in training. We discuss pilots' and AWACS weapons directors' performance within DMT and identify mission tasks most appropriate for DMT.

15. SUBJECT TERMS
Airborne Warning and Control System; AWACS; Distributed Mission Training; DMT; Exercises; Flight Lead Upgrade; FLUG; Simulation; Training;

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Dr Peter Crane
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED		480.988.6561 x-287 DSN 474-6287

CONTENTS

FIGURES

TABLES

SUMMARY

The Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA), is conducting research on the technologies required to develop and support Distributed Mission Training (DMT) and on training applications and strategies for DMT. The objectives of training effectiveness research are to identify high-payoff applications, develop prototype training strategies, and assess the impact of DMT experience. This report describes a research effort assessing the application of DMT to Flight Lead Upgrade (FLUG) training for F-16 pilots.

In FLUG training, pilots learn the skills required to lead flights of two and four F-16s. These skills include mission planning, briefing, debriefing, and flight leadership (situation awareness, tactical execution, work with air weapons controllers, and communication). FLUG training can be resource intensive requiring both friendly and opposing forces. Repeating training flights because an upgrading FLUG pilot fails to demonstrate acceptable proficiency places significant demands on squadron resources. The goal of this research program was to determine whether DMT experience would enhance pilot performance and reduce the number of repeated FLUG training missions. AFRL/HEA researchers worked with wing and squadron leaders at the 27th Fighter Wing, Cannon AFB NM, and identified four vs. four Dissimilar Air Combat Tactics (DACT) and four-ship Surface Attack Tactics (SAT) as potential high-payoff missions for DMT. A five-day DMT–FLUG training protocol was developed to enhance pilot skills for these missions. Between June 1999 and February 2000, twelve upgrading FLUG pilots supported by wingmen, instructor pilots, and air weapons controllers participated in DMT research exercises at AFRL/HEA using this training protocol. Pilot performance within DMT missions and on subsequent aircraft training flights together with feedback from upgrading pilots and their instructors indicate that DMT experience improves both individual pilot skills for tasks that are rarely practiced in the aircraft and leadership skills.

USING DISTRIBUTED MISSION TRAINING TO AUGMENT FLIGHT LEAD UPGRADE TRAINING

INTRODUCTION

The Air Force's Distributed Mission Training (DMT) program is a major advance in ground-based training that will allow pilots and other warfighters to train for complex, multiplayer combat operations using a network of flight simulators and other systems. Chapman (1998) states that,

> The DMT network will be created incrementally, focusing first on team training. F-15C and AWACS *Missions Training Centers* (MTCs) will be the first DMT constituents. MTCs will house the unit's simulators or mission training system, briefing and debriefing systems, threat stations and simulations, and the infrastructure needed for local and wide area networking. (p. 1)

F-15 and AWACS MTCs went into service in 2000, and the first F-16 MTC will be in service by 2002.

Researchers from the Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA), are investigating strategies for incorporating DMT into advanced flying training in operational units. When reviewing the utility of an earlier generation of training systems, Polzella, Hubbard, Brown, and McLean (1987) discovered that many of the instructional features that had been incorporated into Air Force flight training simulators were unwanted and unused. A primary goal of DMT research at AFRL/HEA is to provide commanders and instructors at MTCs with effective and validated training tools and materials including training protocols to meet specific needs, sample scenarios, and performance assessment instruments. The laboratory's objective is to assist Air Force warfighters use DMT systems to effectively and efficiently augment flying training.

Background

Research on training effectiveness of multiship simulation systems has been ongoing at AFRL/HEA for almost ten years. In addition to research on networked simulation technologies activities have focused on application of DMT for continuation training of fighter pilots and air weapons controllers. Hoog (1999) described how DMT systems are being designed to enhance skills that warfighters will employ both as individuals and as members of a team. Effective application of multiplayer simulation for enhancing individual and team skills has been demonstrated for F-15 pilots (Houck, Thomas, & Bell, 1991), F-16 pilots (Berger & Crane, 1993), Tornado pilots and navigators (Huddlestone, Harris, & Tinsworth, 1999), pilots, forward air controllers, and ground forces executing close air support (Bell, et al., 1996), and Air Force Special Operations teams (Nullmeyer & Spiker, in press). F-16 pilots who have flown in a distributed environment have rated DMT as particularly effective for training 4-ship air-to-air employment against multiple enemy aircraft (Crane, Schiflett, & Oser, 2000). F-16 pilots have identified individual skills including radar mechanization (i.e., using the various modes and capabilities of the air-to-air radar to detect, track, and target multiple aircraft), communication, and building situation awareness as being enhanced by DMT. Team skills enhanced by DMT include maintaining mutual support, tactical execution, and flight leadership. Crane (1999) reported that F-16 instructor pilots participating in DMT research would frequently fly as flight leader for the morning mission but would then assign a less-experienced pilot to serve as flight lead during the afternoon. The instructors explained that these pilots were participating in Flight Lead Upgrade (FLUG) training at their squadrons and that DMT was a valuable complement to aircraft training.

Flight Lead Upgrade Training

After graduation from a formal training course, U. S. Air Force fighter pilots must first complete Mission Qualification Training at their assigned unit before serving as mission-ready wingmen. After gaining the required flying hours of experience as a wingman, and having demonstrated solid flying skills and in-flight discipline, pilots can then be selected for FLUG training. Here they will learn to lead an element of two aircraft and eventually an entire flight of four. Although the Air Combat Command (ACC) (1998) specifies general guidance for upgrade training, each fighter wing develops its own program of academics, simulator exercises, and training flights. For F-16 pilots these training flights include a mix of both air-to-air and air-to-ground missions. Even though all upgrading pilots have gained considerable experience as wingmen, some missions are flown relatively infrequently due to airspace and resource limitations.

The 4 vs X Dissimilar Air Combat Tactics (DACT) mission (four F-16s opposed by an unknown number of threat aircraft) is the least practiced mission as it requires at least eight aircraft (four friendly and four or more enemy) plus weapons controller support if available. Even when these resources are available, DACT training missions are often constrained by airspace limitations that prevent teams from employing advanced tactics. Similar resource limits apply to Surface Attack Tactics (SAT) missions that incorporate enemy fighters defending ground targets. As a result, upgrading pilots often find themselves learning to lead highly demanding missions that they have infrequently practiced as wingmen. If the upgrading pilot does not demonstrate the required proficiency during a FLUG mission, the mission must be repeated until the pilot demonstrates the necessary level of expertise. Depending on the specific mission, this can place significant demands on squadron resources.

Objectives

A research program to assess the effectiveness of using DMT to augment FLUG training was undertaken by AFRL/HEA under sponsorship of ACC's DMT office and with the cooperation of the 27th Fighter Wing, Cannon AFB, and the 552nd Air Control Wing, Tinker AFB. The objective of this program was to determine how DMT experience incorporating exposure to numerous air-to-air engagements can increase pilot readiness for FLUG missions and reduce the incidence of missions that were repeated due to noneffective upgrading pilot (NEUP) performance.

The research program encompassed four phases.

- First, training records were reviewed to identify 4-ship FLUG missions that would most benefit from DMT experience and to establish baseline rates for sorties that were repeated due to NEUP proficiency.
- Second, a 5-day DMT-FLUG training protocol was developed targeting these missions.
- Third, DMT-FLUG training events were conducted over a one-year period. During these events, upgrading pilots planned, briefed, led, and debriefed missions of increasing complexity using the Air Force Research Laboratory (AFRL) 4-ship DMT testbed.
- Fourth, transfer to aircraft training was assessed through review of training records and interviews with both upgrading pilots and their instructors.

DMT-FLUG TRAINING PROTOCOL

Review of Training Records

At the 27th Fighter Wing during the review period, FLUG included 14 training missions, 10 in which the upgrading pilot leads a 2-ship element and four leading a 4-ship flight. In April 1999, AFRL researchers reviewed training records for all pilots who had completed FLUG in the previous three years or were currently participating in FLUG. Upgrading pilot proficiency for each training mission is evaluated by an instructor pilot who rates performance on a number of mission elements using a scale ranging from 1: *Performance is safe but indicates a lack of proficiency*, to 4: *Performance reflects an unusually high degree of ability.* A minimum score of 2: *Performance is essentially correct; recognizes and corrects errors*, on all critical elements is required for a mission to be rated complete and effective. A mission that is rated noneffective must be repeated before an upgrading pilot can fly a checkride for FLUG certification. While researchers initially focused on overall mission scores, this proved to be unnecessary as nearly all effective missions were rated 2 and all noneffective missions were rated 1.

Training data for over 30 upgrading pilots show that the refly rates for noneffective performance ranged from 0% for 2-ship night intercepts and less than 3% for 2-ship basic fighter maneuvers and 2-ship basic surface attack to over 22% for 2-ship intercepts. Among 4-ship missions, the highest refly rates, 15% were for 4 vs X DACT and 4-ship SAT (see Figure 1). Further, review of individual scores and instructor comments reveal that noneffective ratings for the 4-ship SAT mission most often resulted from poor reaction to surface and airborne threats rather than for problems with navigation, air-to-surface tactics, or ordnance delivery.

Protocol Development

Results of the FLUG training data analysis were briefed to wing and squadron leaders with the goal of selecting missions to be complemented with DMT. Wing leaders chose to correct 2-ship mission problems using existing resources. Their most significant problem by far

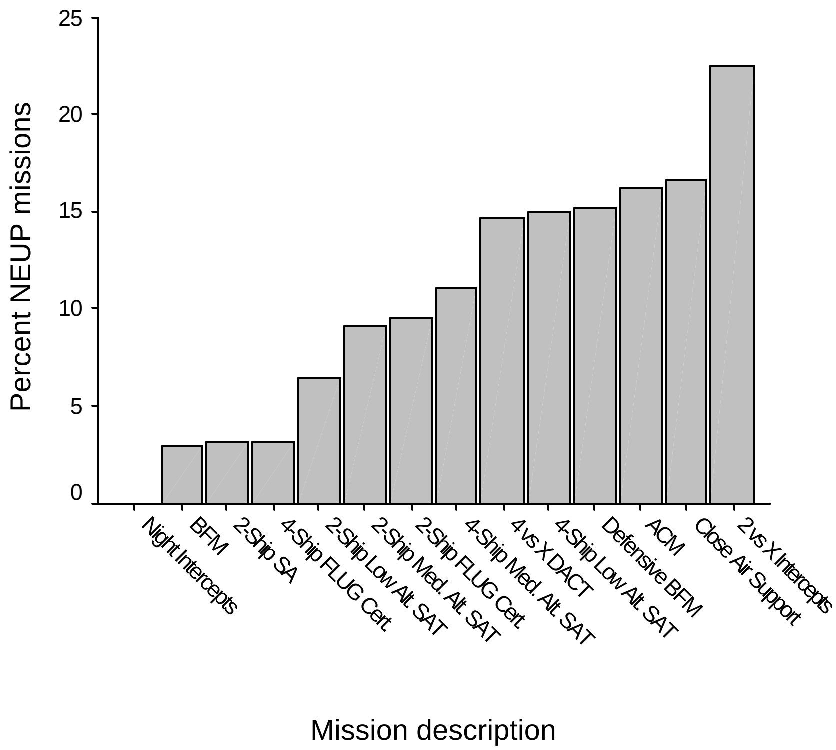


Figure 1. Percentage of FLUG Training Missions Repeated for Noneffective Upgrading Pilot Performance (BFM: Basic Fighter Maneuvers, SA: Surface Attack; FLUG: Flight Lead Upgrade; SAT: Surface Attack Tactics)

was the 4 vs X DACT mission based on cost and difficulties of scheduling so many aircraft and pilots. The 4-ship SAT mission was also selected for additional training with DMT due to its high refly rate. A DMT-FLUG protocol was developed consisting of four missions: 4 vs 4 Sweep, 4 vs X Sweep, 4 vs X Defensive Counterair (DCA)[1], and SAT opposed by both airborne and ground forces. Within these missions, selected DMT FLUG training objectives included briefing and debriefing skills, radar mechanization; assessing the tactical situation; tactical execution; effective communication; mutual support; and maintaining situation awareness. DMT-FLUG missions were designed to closely resemble FLUG flying missions in objectives, mission tasks, and suggested briefing items.

Design of DMT scenarios represents a middle ground between single-ship simulator training and large-force exercises (Crane, 1999). In single-ship simulator training such as learning to respond to in-flight emergencies, an instructor introduces an emergency such as an engine malfunction and then waits for the student to respond. Events are highly scripted and the instructor can readily evaluate good vs poor performance. In contrast, large-force exercises are much less scripted at the level of individual pilots. Evaluators will know where and when forces will engage but will have only limited control over each pilot's experience. The training methodology employed during DMT-FLUG took advantage of the instructor's ability to script the actions of computer-generated forces. The goal of this system was to create robust, focused

[1] Sweep and DCA missions are different types of DACT; other DACT missions include Force Protection (escort) and defending High-Value Airborne Assets (HVAA).

practice scenarios that exercise pilots' skills and provide instructors with the tools required to assess an overall level of proficiency. The scenarios varied in difficulty from a single non-maneuvering enemy formation to a continuous profile containing six maneuvering formation groups and 16 enemy aircraft. Over 60 individual scenarios were available which allowed the instructor to present the FLUG pilot with increasing challenges by changing the tactical variables (see Table 1). Because of the large number of scenarios available, the tactical variables were similar between each FLUG pilot's missions, but no specific scenario was ever repeated between the pilots. The instructor could easily increase or decrease scenario difficulty based on the FLUG pilot's demonstrated proficiency.

Table 1. Variables Used in Programming DMT–FLUG Scenarios

Tactical Variable	Values Used in DMT–FLUG
Number of enemy aircraft	4 to 16 in one or more waves
Number of groups	1 to 6
Aircraft types	Fighters, low-level strikers, high-fast flyers
Rules of engagement	Visual identification required or beyond visual range
Enemy level of awareness	Unaware or aware
Permanent kill removal	Off (Shields-up) or On (Shields-down)
Mission type	Offensive sweep or defensive combat air patrol
Formations	Single heavy group
	2 groups divided in range
	2 groups divided in azimuth
	2 groups divided in altitude
	3 groups in champagne or vic formation
	Fighters protecting strikers
	Fighters plus high-fast flyers
	Maneuvers including flank, beam, drag, spin, and post-hole.

Based on the training objectives and logistical considerations, a four and one-half day, intensive protocol was developed with pilots flying two DMT missions per day with each mission consisting of several scenarios (see Table 2). Each mission included a one-hour briefing, one-hour simulator mission, and a one and a half-hour-long debrief. Teams consisting of two upgrading FLUG pilots, two wingmen, an instructor pilot, and one or two AWACS weapons controllers flew each mission type (i.e., 4 v 4 Sweep, 4 v X Sweep, DCA, and SAT) twice. This gave each FLUG pilot the opportunity to brief and lead each mission type. Each upgrading pilot also flew in the Number 3 position leading the second element within the flight for three missions and observed one mission from the AFRL DMT control console. The instructor pilot flew four missions during the week in the Number 2, 3, or 4 position, which enabled him to assess the strengths and shortfalls of the simulators and allowed the other pilots to observe one training mission from the console. Approximately 7-8 scenarios were flown during

Table 2. DMT-FLUG Five-Day Training Schedule

	Mon.	Tue.	Wed.	Thu.	Fri.
am	Familiarization	4 v 4 Sweep	4 v X Sweep	4 v X DCA	SAT – Medium and Low Altitude
pm	4 v 4 Sweep	4 v X Sweep	4 v X DCA	SAT – Medium and Low Altitude	

each sweep mission, 3-4 DCA scenarios, and 2 scenarios (one medium altitude and one low altitude) were flown during the SAT missions. The instructor pilot flew four missions during the week, and observed the others from the AFRL DMT control console; one of the two wingmen observed from the console when the instructor flew a mission. Characteristics of the missions were:

- The 4 vs 4 Sweep mission consisted of scenarios limited to four enemy aircraft in two groups or less (Figure 2). The first several scenarios required the FLUG pilots to visually identify (VID) the target aircraft before they could employ ordnance. Suggested briefing items included VID mechanics, sorting and targeting plan, and missile shot/kill criteria. Simulator "shields" were up which meant that the F-16 pilots could not be killed by the threat aircraft.

- The 4 vs X Sweep mission limited the enemy to three groups with no maneuvering restrictions (Figure 3). Simulator shields were down which allowed for permanent kill removal. High, fast, flyer procedures and tactics were introduced as a new briefing item.

- The 4 vs X DCA mission was flown shields-down and emphasized combat air patrol (CAP) management (Figure 4). Unlike the Sweep scenarios that were terminated after one force was destroyed, DCA scenarios ran continuously for a 15-20 min vulnerability period during which the F-16 force was tasked to defend their home station from attack. Enemy formations were limited to three groups. However, the enemy groups had no range, azimuth, or altitude restrictions and a mix of hostile and bogey groups was presented. Up to six aircraft engaged the F-16s at any time during the scenario with up to 16 total enemy aircraft in multiple waves over the duration of the vulnerability period. Pilots needed to reform their CAP after each wave and manage their fuel and missiles. In addition, enemy surface-to-air missiles were inserted along the western edge of the gaming area. These missiles would engage F-16s that strayed too far past their assigned patrol area.

- The SAT mission contained a low and medium altitude profile. In addition to enemy aircraft, enemy surface-to-air missiles and antiaircraft artillery were embedded in the scenario to evaluate threat awareness and reactions (Figure 5). The ingress route, target, weapons load, and known enemy ground positions remained constant between the two scenarios; however, the number and location of enemy aircraft varied. This mission stressed decision making and air-to-air tactics against enemy aircraft given that the F-16's primary role was air to ground.

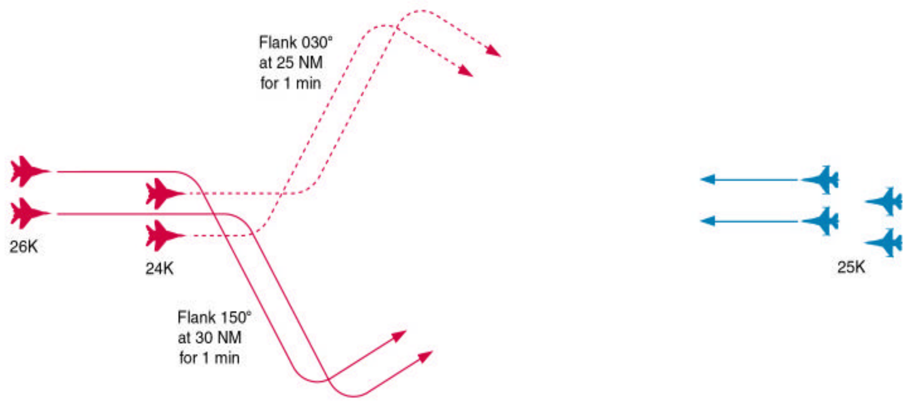


Figure 2. 4 vs 4 Sweep Scenario

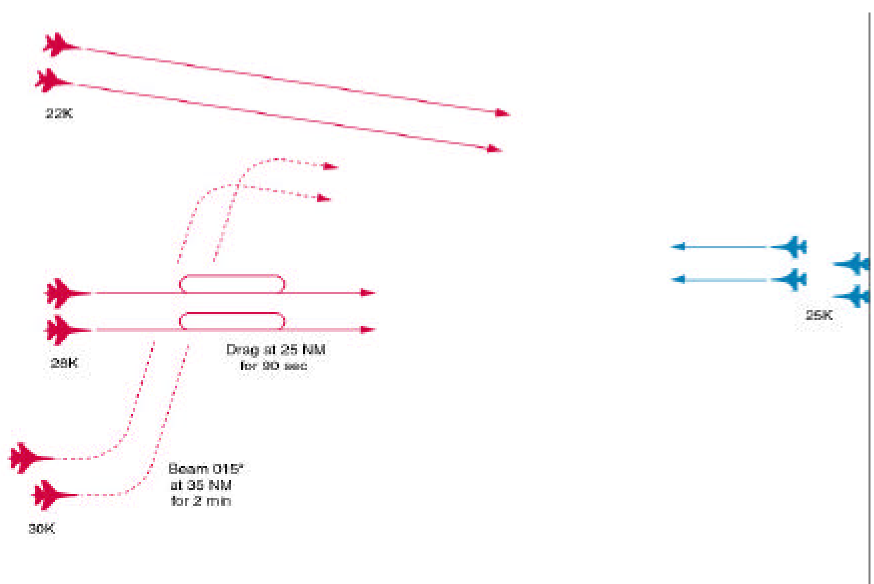


Figure 3. 4 vs X Sweep Scenario

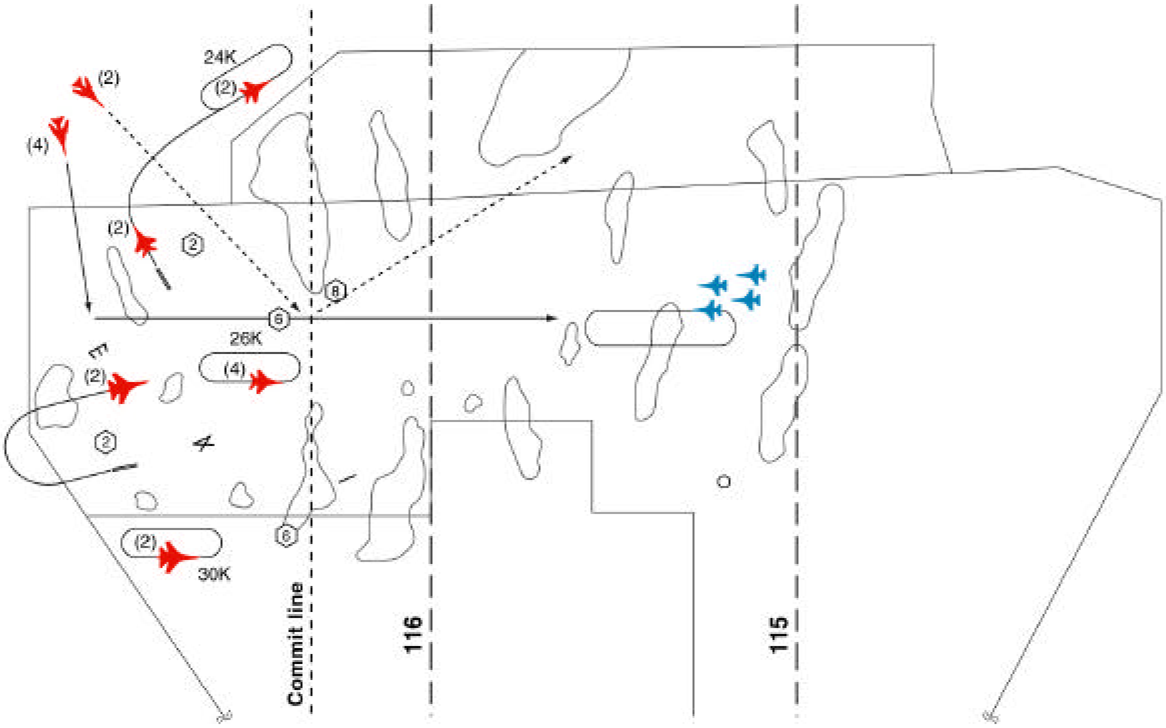


Figure 4. Defensive Counter Air (DCA) Scenario

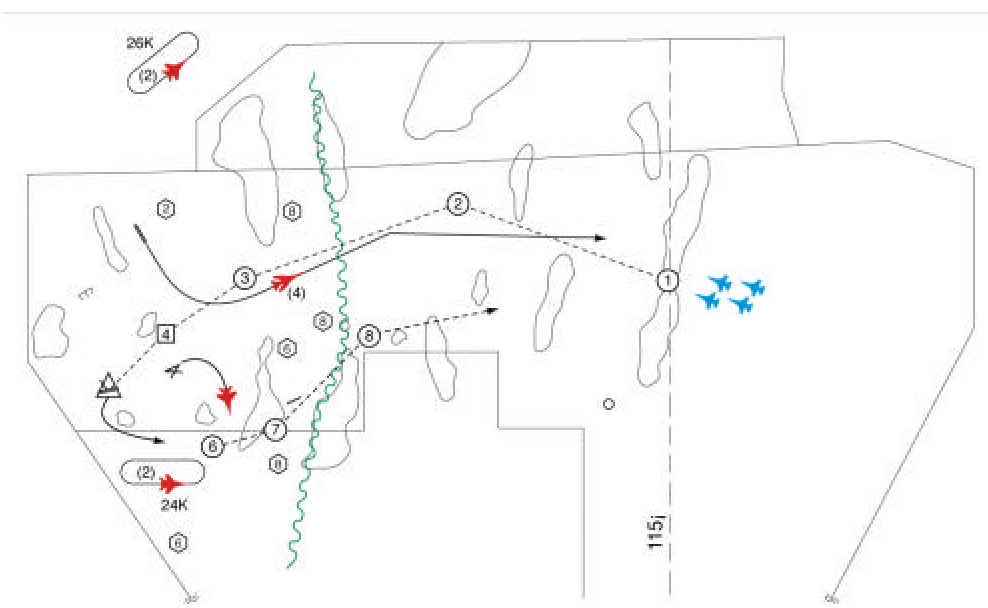


Figure 5. Surface Attack Tactics (SAT) Scenario

DMT–FLUG TRAINING EVENTS

Systems

DMT-FLUG training was conducted using AFRL/HEA's DMT testbed system, which consists of four interlinked F-16 simulators (Figure 6a), a control and observation console (Figure 6b), a constructive threat system providing semi-autonomous, computer-generated aircraft, long-distance network to an AWACS simulator (Figure 6c) located at Brooks AFB in San Antonio, TX, and a mission replay/debrief system (Figure 6d). For the SAT missions, the Air Force Information Warfare Center at Kelly AFB, TX, provided a constructive, integrated air defense system. For a more complete description of AFRL/HEA's DMT testbed, see Crane, Schiflett, and Oser (2000).

Figure 6. AFRL/HEA DMT Testbed Systems: a) F-16 Simulator, b) Control and Observation Console, c) AWACS Simulator, and d) Replay/Debrief System

Schedule

DMT-FLUG training events were conducted in June, August, and October 1999, and February 2000. Participants were selected by their squadrons based on availability and status within the FLUG program. Ideally, the upgrading pilots had completed their 2-ship FLUG training flights and were beginning their 4-ship flights. Due to deployments and other commitments, pilots in all stages of FLUG training participated. Weapons controllers from the 552nd Air Control Wing and the 970th Airborne Air Control Squadron were assigned by their squadrons based on availability. All pilots and weapons controllers were combat mission ready.

Participants

Twelve upgrading pilots with 200 to 485 flight hours (median = 410) in the F-16 participated in DMT-FLUG together with 6 instructor pilots, 9 wingmen, and 10 weapons controllers. None of the upgrading pilots had any previous experience in other fighter aircraft. One pilot was called away due to a family emergency after one DMT-FLUG mission; however, one of the wingmen was also in FLUG training and replaced him in the sample.

RESULTS

Three types of data were collected to assess the effect of DMT on FLUG training: performance in subsequent aircraft training events, performance during DMT-FLUG missions, and feedback from participants.

Performance in Subsequent Aircraft Training

As of 1 September 2000, 8 of the 12 upgrading pilots who participated in DMT-FLUG have successfully completed the FLUG program without any repeated rides. Two pilots, however, were accepted into the B-2 program, and their squadron waived the requirement for a 4 v X DACT ride for these pilots. Both successfully completed a FLUG checkride, which is a 4-ship SAT mission. Eight pilots successfully completed the 4 v X DACT ride on the first attempt. One DMT–FLUG pilot was required to repeat his 4 vs X DACT mission for noneffective performance on his mission briefing. This pilot participated in DMT FLUG in October 1999 and did not fly the DACT mission until April 2000. In addition, this pilot flew his DACT mission as part of an exercise consisting of several 4-ship air-to-air missions so that scheduling an additional 4 vs X sortie was not required. The remaining pilot was still in FLUG.

Performance in DMT——FLUG

Each scenario flown during a DMT–FLUG simulator period was graded by a laboratory subject-matter expert. Initially the rating scales and mission tasks were similar to their mission grade sheets used at home station. However, early data analyses identified several mission tasks that showed little variability over the week and some mission tasks that were rarely observed during DMT-FLUG missions. To overcome these difficulties, the number of graded tasks was reduced and a new scale was devised to help obtain more meaningful information. The new 3-level rating scale (-, 0, +) asked the subject-matter expert to evaluate mission performance as being either below average for an upgrading FLUG pilot, average, or above average. Coincident with the new rating scale, benchmark scenarios were introduced to better evaluate pilot performance during the week. Two sets of benchmark scenarios with equal difficulty were selected. Benchmark scenarios used with upgrading pilots on the same team were essentially mirror images. The first benchmark scenario was administered during the 4 vs 4 Sweep mission, and the second was given during the 4 vs X DCA mission. Six pilots have been evaluated using the new scale and benchmark scenarios. The overall performance between their benchmark scenarios improved for all six FLUG pilots. Several individual mission tasks also showed noteworthy improvement in half or more of the comparisons. These areas included mutual support, tactical decision making, correct picture call, work with AWACS weapons controllers, tactical execution, radar mechanization, and targeting/sorting all bandits (see Figure 7).

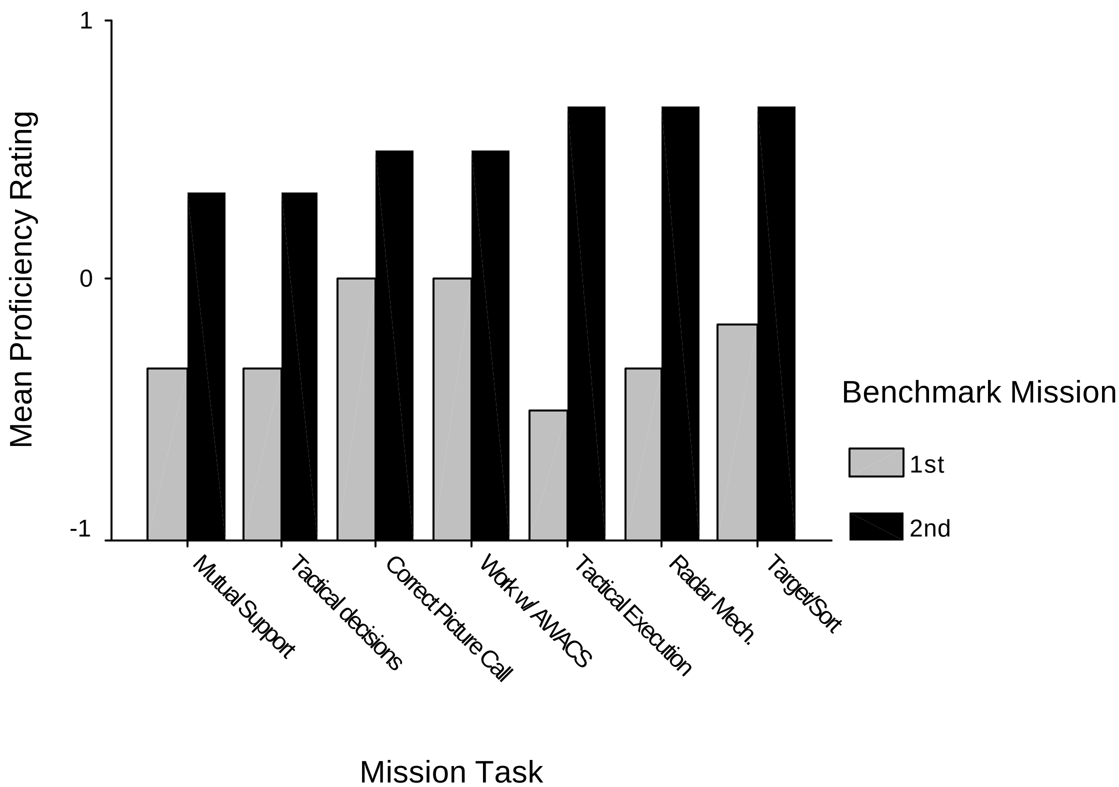


Figure 7. Changes in Mean Mission Performance Ratings Between the First and Second Benchmark Missions During DMT–FLUG Training

Increases in performance scores between the first DACT mission (4 vs 4) and the third (DCA) were not uniform across skills. Scores for individual skills increased consistently from the first mission to the third. An individual radar skill, *detect all targets* (Figure 8a), and an individual communications skill, *correct picture call* (Figure 8b) are examples. Improvements in scores for team skills, however, required more DMT experience. A team radar skill, *target and sort all bandits* (Figure 8a), and a team communications skill, *work with AWACS weapons controller* (Figure 8b), decreased as mission complexity increased from 4 vs 4 to 4 vs X. With additional experience in complex scenarios, however, performance scores increased.

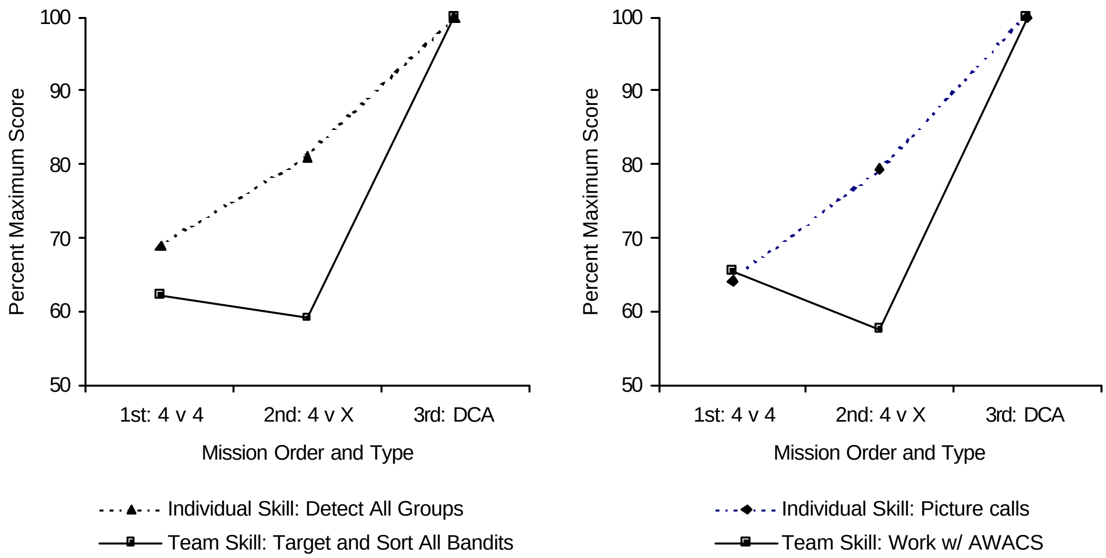


Figure 8. Changes in Mean Performance Scores for Individual and Team Skills:
a) radar skills, b) communication skills

The number of times that a flight member was killed by enemy action increased slightly between the first and last air-to-air missions; however, this change was small compared to the increased complexity of the scenarios and the number of enemy aircraft. The number of total fratricide incidents was reduced from six during the 4 vs 4 missions, to only one incident during the 4 vs X DCA missions.

Pilot Feedback

Pilots and weapons controllers were asked to provide feedback to the research team after each mission and at the end of the week. Comments fell into three categories: system problems, training effectiveness, and recommendations.

Comments regarding system problems included minor issues that were typically corrected within a simulator session and more significant problems with the testbed. Minor problems include head-tracker failures, radio communications not correctly recorded for debrief, too much/too little air conditioning in cockpit, and visual system failure requiring restart. More significant comments include inability to determine aspect of another aircraft beyond 4,000 feet (see Crane, Schiflett & Oser, 2000), and modeling of threats and countermeasures.

Pilots and weapons controllers participating in the DMT-FLUG program agreed that DMT provides effective training for multiship, multibandit air combat. Strengths of the system are the opportunity for multiple engagements within an hour and the high level of situation awareness provided by the replay system during debrief. Specific skills cited include radar mechanization, work with weapons controllers, communication, tactical execution, situation awareness, briefing, and confidence building. Pilots also agreed that within-visual-range air combat skills and aircraft handling are not well trained in the testbed DMT system.

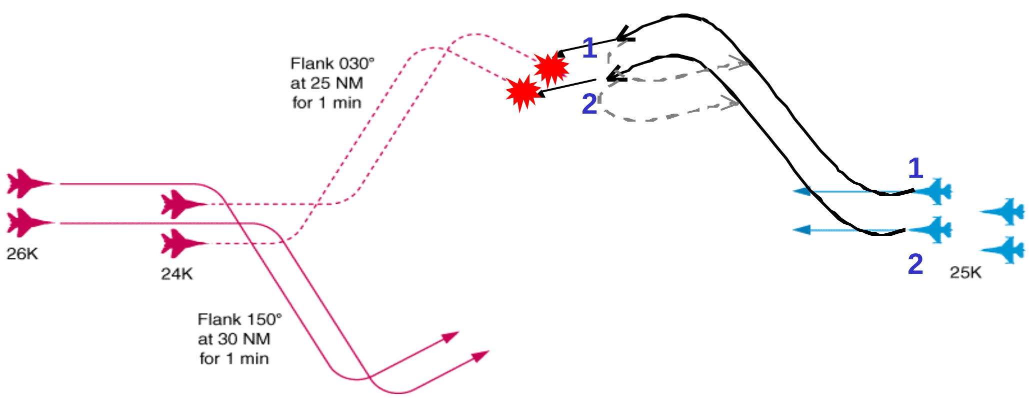
In addition to correcting system problems, participants offered several recommendations for improving DMT overall and DMT-FLUG. There was disagreement whether an intensive syllabus lasting several days such as DMT-FLUG was more effective than the more traditional simulator mission first followed by the aircraft mission approach. While some pilots wanted to rehearse each mission before flying it, all agreed that there is considerable benefit to an intensive DMT air-combat program. One instructor pilot stated that, “Pilots overcome simisms first, then demonstrate initial proficiency, and there is exponential improvement after that.” A second recommendation was to integrate the weapons controller into the brief and debrief rather than use telephone brief/debrief between training sessions. Suggestions included video teleconference and interactive whiteboards.

Several weeks after returning to Cannon AFB, questionnaires were sent to pilots regarding the effectiveness of DMT. Responses have been received from 9 of the 17 pilots who participated in DMT-FLUG: 5 upgrading pilots, 2 instructor pilots, and 2 wingmen. Four of the five upgrading pilots evaluated DMT-FLUG experience as significantly transferring to the aircraft; the fifth pilot rated transfer as moderate. Specific skills that were cited as showing transfer were briefing, communications, beyond-visual-range tactics, radar mechanization, situation awareness, decision making, leadership, plus developing and using backup / contingency plans. One of the upgrading pilots expressed concern that DMT is too easy and lacks distracting elements of actual flying such as pulling g’s, noise, and vibration. One IP rated DMT-FLUG as transferring significantly to the aircraft citing pacing and situation awareness as skills well trained in DMT. The other IP, however, stated that there was no transfer and that DMT is no more than an expensive video game that does not provide useful training. The two wingmen stated that DMT transferred moderately to the aircraft with the most positive transfer for situation awareness, radar mechanization, and 4-ship tactics. All pilots agreed that the 4 vs X DCA mission was the most effective and that the SAT mission was least effective. Pilots were asked whether they would recommend that DMT be used in an intensive syllabus as in DMT-FLUG or a more traditional approach of alternating simulator and aircraft training missions. Five of the nine pilots preferred the traditional approach so that DMT missions could be tailored to specific aircraft training flights although one pilot expressed concern that this would slow the overall pace of training. Two pilots preferred the intensive approach and two did not respond. Recommendations for how frequently pilots should use DMT ranged from “never” to “any day that I’m not flying.”

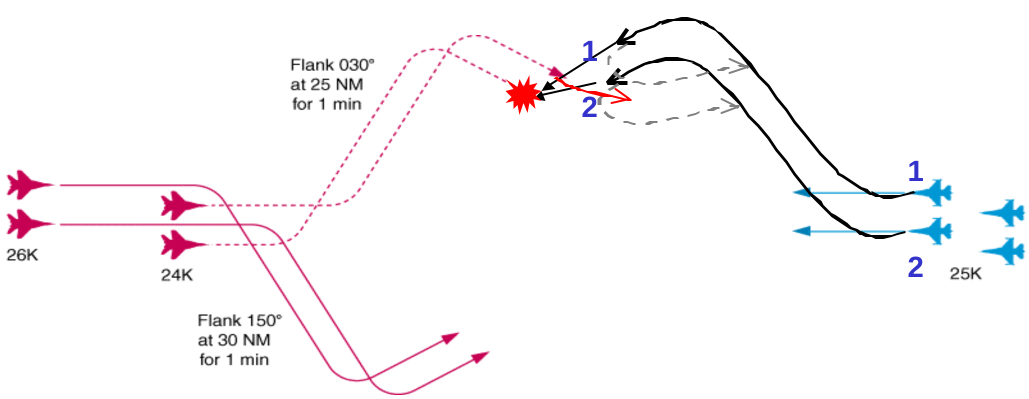
DISCUSSION

As applied to FLUG training, results to date demonstrate that experience in DMT enhances leadership skills for multiship, multibandit air combat. This is most likely a function of both DMT system capabilities and constraints on pilots’ ability to train in the aircraft that limit opportunities for gaining experience over a wide range of tactical situations. Observations of pilots during DMT–FLUG exercises demonstrated that increases in mission performance resulted from both enhanced skills and from opportunities to review missions and to assess the results of individual actions. The following examples illustrated these effects:

- One upgrading pilot flying the 4 vs 4 scenario depicted in Figure 2 had briefed that for this situation (enemy aircraft groups separated in azimuth), the F-16s would divide into two elements and bracket to the outside of the enemy groups with pilots flying in the numbers 1 and 3 positions shooting the far north and south bandits respectively. The upgrading flight leader also briefed that F-16 pilots were to fire radar guided missiles and then turn away before entering enemy missile range, Figure 9a. The upgrading pilot, however, lacked the skills required to lead the flight, select the appropriate tactical plan, communicate on the radio, and use the radar to sort the formation before turning away. The upgrading pilot fired unsorted into the bandit formation and turned away while the wingman correctly sorted his target. Both missiles ended up killing the same aircraft and the F-16 pilots were required to expend time and fuel defending themselves from the surviving MiG, Figure 9b. After additional practice, the upgrading pilot improved his leadership and radar mechanization skills and was able to focus on more complex team skills.



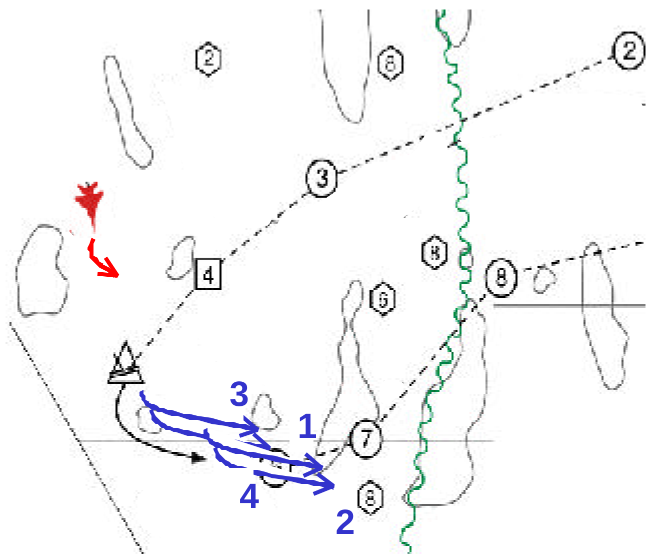
a) Briefed mission plan



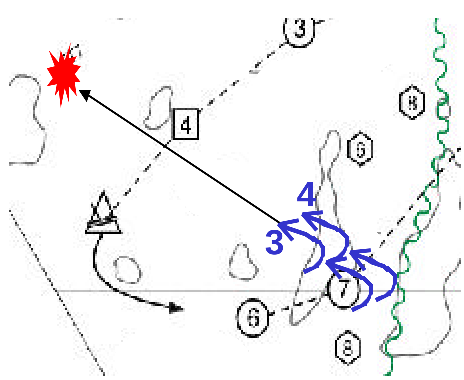
b) Actual execution of DMT mision

Figure 9. Briefed Plan Compared to Actual Execution of a 4 v 4 Sweep Mission

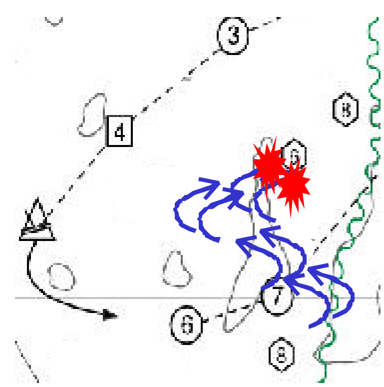
- Another upgrading pilot was flying as Number 3 on a SAT mission leading the second element within the flight (see Fig. 5). The F-16s successfully defended themselves against several MiG-29s and dropped their bombs on target. As the F-16s were egressing the target area, a single MiG was detected by AWACS many miles behind them (Fig. 10a). The upgrading pilot turned away from the formation supported by his wingman and shot down the MiG (Fig. 10b). When they turned back toward friendly airspace, however, they were engaged by a previously briefed surface-to-air missile and both killed (Figure 10c). During debrief, it was clear that the MiG was not a threat and the F-16s could have flown home safely. By diverting to engage the MiG, the upgrading pilot pulled the formation off course allowing his element to be engaged by the surface-to-air missile. While the pilot's air combat skills were excellent, his decision to engage was a serious error.



a) Tactical situation as F-16s eggressed target area; a single MiG-29 is detected by AWACS



b) Upgrading FLUG pilot flying as second element lead turns to attack MiG-29



c) F-16s shot down by SAM-6 surface-to-air missile after failing to return to planned course

Figure 10. Example of poor situation awareness and decision making during SAT mission

One of the objectives of DMT–FLUG research was to identify the ways in which DMT experience could increase pilot readiness for FLUG missions. These examples illustrate two training benefits of DMT. The first is providing increased opportunities to train individual skills that must take place in a multiplayer context. Radar sorting and targeting requires multiple friendly and enemy aircraft; opportunities to practice this skill in the air are highly limited. DMT provides many opportunities to practice this skill in a naturalistic context and within a short period of time. This observation is in agreement with Bell (1999) and Schneider (1989) who propose that multiple opportunities to practice a skill in a variety of contexts will result in substantial performance enhancement. A second training benefit from DMT is the opportunity to gain experience in making decisions. Klein (2000) asserts that lack of experience is the primary reason for poor decision making. Without high levels of experience, decision makers often fail to recognize the implications of various situations and select inappropriate courses of action. Experience in DMT can augment aircraft experience by providing pilots with multiple opportunities to execute various tactics and to review the results of their actions.

In the next iteration of the DMT-FLUG training effort, we will be developing more comprehensive training and measurement capabilities that will permit us to identify which behaviors improve and how DMT helped in the improvement process. Our findings to date indicate that minimum capabilities for effective DMT include the following:

- DMT systems must be supported by programmable scenario generation tools that permit the incorporation of instructional principles and training strategies to foster skill development and retention.

- Mission replay and after-action reviewing capability are necessary capabilities for an instructionally viable training and rehearsal system.

- A construct-oriented individual, team, and mission performance measurement system.

Simple practice or free-play are not efficient training strategies. Programmable scenario generation tools including computer-generated threats with the capability for autonomous action permit instructors to take advantage of findings from research on instructional principles to design training and rehearsal events that will meet specified objectives. In multiship air combat, training objectives for upgrading pilots include learning to recognize enemy aircraft formations and selecting an appropriate tactic, communicating the plan to the rest of the flight, executing the plan, and changing tactics as required. The programmable scenario generation tools in DMT-FLUG were used to create enemy formations and tactics that varied across a number of dimensions as summarized in Table 1. This range of scenarios combined with the opportunity for teams to fly several scenarios in an hour provide upgrading pilots with opportunities to gain experience with many more tactics and situations than would be possible in the aircraft.

Another key element in the success of DMT is the replay and debrief facility. In the AFRL testbed, each cockpit's radar, radar warning receiver, head-up display, and stores management system are recorded and played back synchronized with a plan view display and all radio communications. The flight leader can pause, rewind, or zoom the display as required. Using the replay system, pilots can review the information that was available to them inside the cockpit together with the plan view display's depiction of the complete tactical situation.

Execution errors, poor communication, and unplanned contingencies are quickly apparent. Debriefs were limited to 90 minutes for scheduling purposes, which forced teams to focus on high-level skills such as communication and execution without getting absorbed into analysis of individual, procedural skills.

Finally, it is important to note that the results presented in this report represent an evolution of our training paradigm from one of structured practice to one that is more focused on both objectives-driven instruction and construct-oriented performance measurement. The lessons learned from this initial DMT-FLUG effort have provided considerable insight into the problems and needed capabilities associated with implementing a high-fidelity, adaptive training and rehearsal system for Air Force pilots. The following summary describes future directions in research being undertaken at AFRL/HEA based on the results of DMT-FLUG.

Training Needs Assessment and Content Validation

In continuing DMT-FLUG research, we will be conducting systematic assessment of training needs at other F-16 bases. The goal of the needs assessment is to elaborate the specific tasks and mission areas that are problematic for pilots in upgrade training. Additionally, the needs assessment will provide the necessary data to develop an instructionally principled curriculum. By focusing on key needs, we can design a syllabus that fosters the development and retention of skills needed for FLUG success. Moreover, the needs assessment will complement our current research activities in the definition of mission-essential competencies, i.e., the knowledge, skills, attitudes, abilities, and capabilities required for combat mission readiness. This effort will help us develop a more comprehensive, objectives-oriented syllabus for DMT-FLUG and identify the important performance parameters associated with mission effectiveness. It will also help us in the development of metrics to quantify training impact in terms of combat mission readiness and performance.

Development of Performance Criteria and Measurement Instruments

We are currently developing and testing evaluation instruments for individual and team effectiveness based on mission-essential competencies. By adopting a competency-based approach to training development and evaluation, we are developing data collection and analysis methods for use across the entire spectrum of DMT activities (e.g., mission preparation, briefing, execution, and debriefing). Measurement techniques are being developed for analysis of verbal communications, pilots' mental models, team processes, and mission outcomes.

- Content-analysis methods. Content-analysis instruments are being developed to evaluate verbal communications to better understand the quality of briefings, within-mission communication, and debriefings. In addition, measures of attitudes toward training, motivation, and perceived application and utility of the training have been developed for use in other training research and will be extended to FLUG.

- Mental modeling assessments. We are also conducting a series of studies on structured assessments of learning such as situational judgment assessments, mental modeling, Pathfinder, concept mapping, and multidimensional scaling. These are being applied to assess learning and understanding at both individual and team levels.

- Process and outcome-oriented measurement. Using mission-essential competency definitions, it is possible to identify process-oriented behaviors that are associated with effective mission performance. We will then be able to develop process-oriented measures that will help us quantify the effects of DMT experience on individual and team knowledge acquisition, crew coordination/flight integrity (including leadership and assertiveness), situational awareness, communication, decision making/risk management, task management, and mission planning/debrief. As a part of these activities, we will develop, test, and validate protocols to capture data related to the identified processes. The key process behaviors and metrics will be used to further refine training objectives and to identify opportunities to improve training content and training policy.

Finally, we are evaluating the reliability and validity of mission outcome measures including exchange ratios and missile effectiveness. Based on this evaluation, we will be refining, automating, and applying measures for simulator and flying performance. It is critical that any developed measurement system provide reliable and valid data to demonstrate that training has had an impact on actual aircrew competencies, attitudes toward training, motivation to train, expectations regarding training and transfer, knowledge mastery and subsequent job performance. Furthermore, the data and instrumentation will serve both a formative assessment function by providing feedback on problem areas in the training and a summative function by permitting cost and mission impact assessments.

SUMMARY

DMT-FLUG research has demonstrated both the utility and effectiveness of DMT to complement aircraft training. DMT supports upgrade training by providing opportunities for pilots to plan, brief, fly, and debrief many more air-to-air missions than currently possible in aircraft. In addition, DMT provides instructors the capability to choose scenarios that exercise selected skills. Subsequent DMT-FLUG research will focus on developing a comprehensive training syllabus that will incorporate needs analysis, specification of essential competencies, scenario development and selection based on principles of instruction, and performance measurement systems that will assess both mission outcome and team processes.

REFERENCES

Air Combat Command (1998). *F-16–Aircrew Training*. Air Force Instruction 11-2F-16, Vol 1.

Bell, H.H. (1999). The effectiveness of Distributed Mission Training. *Communications of the ACM, 42(9).*

Bell, H.H., Dwyer, D.J., Love, J.F., Meliza, L.L., Mirabella, A., & Moses, F.L. (1996). *Recommendations for planning and conducting multi service tactical training with Distributed Interactive Simulation technology (A Four-Service Technical Report).* Alexandria, VA: U. S. Army Research Institute.

Berger, S. & Crane, P. (1993). Multiplayer simulator-based training for air combat. In, *Proceedings of 15th Industry/Interservice Training Systems Conference*, Orlando, FL: National Security Industrial Association.

Chapman, R. (1998). *Air Combat Command concept of operations for Distributed Mission Training*. Langley AFB, VA: Headquarters, Air Combat Command.

Crane, P., Schiflett, S.G., & Oser, R.L. (2000). *RoadRunner 98: Training effectiveness in a Distributed Mission Training exercise* (AFRL-HE-AZ-TR-2000-0026). Mesa, AZ: Air Force Research Laboratory, Warfighter Training Research Division.

Crane, P. (1999). Designing training scenarios for distributed mission training. Presented at: *10th International Symposium on Aviation Psychology*, Columbus, OH, April 1999.

Houck, M.R., Thomas, G.S., & Bell, H.H. (1991). *Training evaluation of the F-15 advanced air combat simulation*. (AL-TP-1991-0047 AD A241875). Williams Air Force Base, AZ: Armstrong Laboratory, Aircrew Training Research Division.

Hoog, T. (1999). Distributed Mission Training overview. Presented at: Distributed Mission Training Implementation, S. Swain, Chair, *'99 Industry/Interservice Training Systems Conference*, Orlando, FL.

Huddlestone, J., Harris, D., & Tinworth, M. (1999). Air combat training-The effectiveness of multi-player simulation. In, *Proceedings of '99 Industry/Interservice Training Systems Conference*, Orlando, FL: National Security Industrial Association.

Klein, G. (2000). How can we train pilots to make better decisions? In, *Aircrew Training and Assessment*, H.F. O'Neil, Jr. & D.H. Andrews, Eds. Mahwah, NJ: Lawrence Erlbaum Associates.

Nullmeyer, R.T. & Spiker, VS. A. (in press). The importance of crew resource management in MC-130P mission performance: Implications for training effectiveness evaluation. *Military Psychology*.

Polzella, D.J., Hubbard, D.C., Brown, J.E., & McLean, H.C. (1987). *Aircrew training devices: Utility and utilization of advanced instructional features (Phase IV – Summary report).* (AFHRL-TR-87-21). Williams AFB, AZ.: Air Force Human Resources Laboratory, Operations Training Division.

Schneider, W. (1989). Getting smarter quicker: Training more skills in less time. *Science and Public Policy Seminar*. Washington, DC: Federation of Behavioral, Psychological, and Cognitive Sciences.