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Evaluation of two wide-field-of-view display systems for air-combat training

Peter M. Crane*

Abstract — A simulator system for training air-combat skills was evaluated by having teams of experienced pilots fly simulated missions. The simulators used were equipped with two different types of wide-field-of-view visual display systems. Pilot evaluations demonstrated that wide-field-of-view displays are necessary for multiship simulator training, even for tasks considered to be non-visual.

Keywords — Human factors, large displays, pilot training, projection CRTs, simulators.

1 Introduction

Simulators for tactical aircraft are invaluable tools for training for the many tasks necessary to employ the weapons system, including instrument navigation, emergency procedures, refueling, and operation of electronic systems. Most of the currently operational simulators are designed to train these skills and are equipped with only limited visual display systems, since the primary training objectives concern systems within the cockpit. These simulators also operate as a single aircraft flying without a wingman. Single-ship operations, however, are very uncommon in air combat. Typically, fighters fly in elements of at least two and more-often four aircraft supported by an air weapons controller^a facing an enemy force at least as large or larger. Combat-oriented training for force-on-force operations requires much more information about events outside the aircraft, and therefore requires wide-field-of-view visual displays and the opportunity to interact with both friendly and enemy aircraft. A simulation system with such capabilities could provide training for tasks which are difficult to practice in actual aircraft, such as defense against surface-to-air missiles (SAMs) and operations against large enemy forces. Although many of these tasks are conducted beyond visual range, pilots report that visual simulation is necessary to maintain tactical formation with allied aircraft, employ short-range missiles, provide mutual support, and to disengage and re-attack.¹

2 Multiship simulation research

Armstrong Laboratory's multiship simulation system is an interactive network of manned and computer-generated forces which supports many types of air-combat training. The system consists of two high-fidelity F-15 cockpits, two lower-fidelity F-16 cockpits, an AWACS air weapons controller station, an exercise-control and

^aAn air weapons controller is an officer who monitors a radar display and vectors fighters towards enemy aircraft. Controllers may be ground-based or on board airborne warning and control (AWACS) aircraft.

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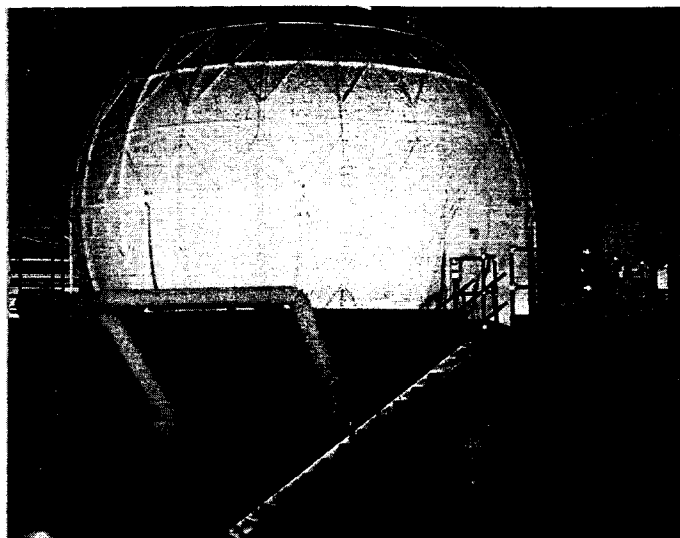


FIGURE 1 — McDonnell-Douglas full-field-of-view dome.

videotaping station, and a computer-generated threat system which provides up to six threat and four friendly aircraft plus surface threats. The F-15 cockpits are integrated with wide-field-of-view visual display systems that provide imagery from the General Electric Advanced Visual Technology System, which is the prototype for the CompuScene IV.

The multiship simulation system was developed as part of the Multiship Research and Development (Multirad) program of research on the use of ground-based training to increase mission effectiveness of air-combat pilots. The objective of the Multirad program is to identify mission tasks and skills which are appropriate for multiship simulator-based training and to determine the design requirements for such a system. The initial evaluation of the prototype system was the Training Requirements Utility Evaluation (TRUE), which was conducted from October 1992 through January 1993. The display systems used in the TRUE were the McDonnell-Douglas Full-Field-of-View Dome System and the Armstrong Laboratory Display for Advanced Research and Training (DART).

3 Display systems

The McDonnell-Douglas system is a 7.3-m (24-ft.) diameter dome (Fig. 1), which displays the full field of view observable from a fighter cockpit.² Full dome coverage is provided through six background projectors and a head-tracked 40° area-of-interest (AOI) projector (Fig. 2). Only the three forward background projectors and the AOI were used in the TRUE evaluation. Luminance of the forward channel was 6.9 cd/m² with a resolution of 4.3 arc-minutes/pixel. For the AOI, the luminance was 10.3 cd/m² with 2.4 arc-minutes/pixel. The maximum contrast ratio in the AOI is 25:1.

The DART is a dome-like display system consisting of eight segments of a dodecahedron which surround the cockpit (Fig. 3).

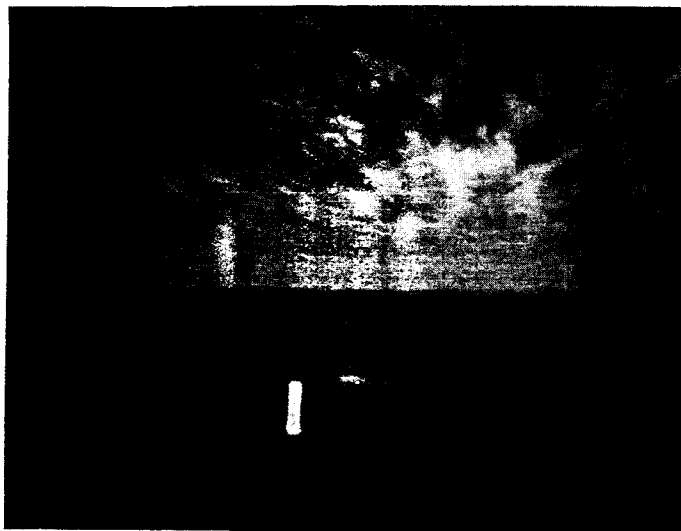


FIGURE 2 — Interior of full-field-of-view dome.

Each segment is a rear-projection screen approximately 1 m from the pilot's head (Fig. 4). Imagery is projected onto the screens from CRTs with a peak screen luminance of 86 cd/m^2 , a resolution of 4.75 arc-minutes/pixel, and a maximum contrast ratio of 50:1.³ Imagery was projected to only six of the screens at a time, as controlled by a head tracker. The DART's field of view is 300° horizontal 200° vertical. Unlike the Dome pilot, the DART pilot cannot see to the rear of the aircraft.

4 TRUE objectives

The primary objective of TRUE was to evaluate the strengths and weaknesses of the multiship simulation system including the visual displays by relating pilot and air-weapons-controller evaluations of component fidelity to rated training effectiveness. The display systems were evaluated for their capability to support air-combat training

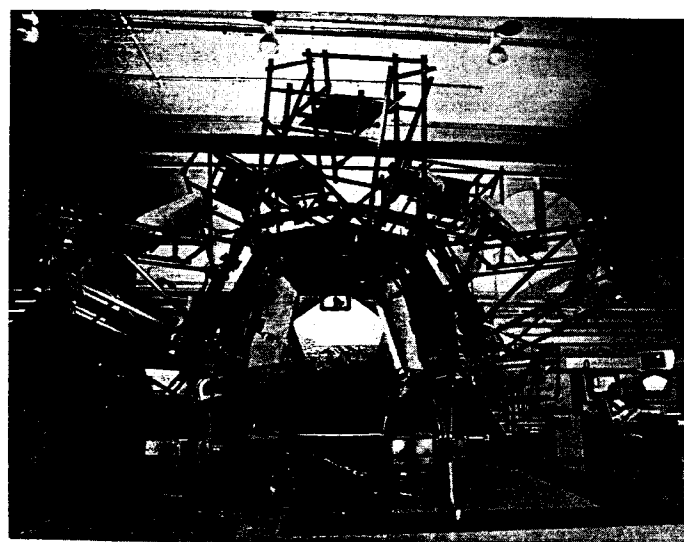


FIGURE 3 — Armstrong Laboratory Display for Advanced Research and Training (DART).

ing using mission scenarios which required both beyond-visual-range and within-visual-range tasks.

4.1 Procedures

TRUE consisted of four 1-week training exercises for teams of F-15 pilots and air weapons controllers. Three or four teams participated each week with a team consisting of a lead pilot, a wing pilot, and a controller. Each team flew offensive and defensive counterair missions against a force of up to six aircraft plus surface threats. During each of seven simulator sessions, a team flew their mission up to four times with the enemy aircraft using different tactics each time. After each simulator session, teams reviewed videotapes of the engagements and completed an evaluation questionnaire. Participants were also asked for their evaluation of the Multirad system during daily meetings and during individual interviews. In addition to the team exercises, some pilots flew 1-vs.-1 air-combat engagements between the two cockpits. These engagements emphasized visual target acquisition, short-range weapons, and basic fighter maneuvers (BFM).

4.2 Participants

Twenty-three USAF F-15 pilots and 13 air weapons controllers participated in TRUE exercises. Pilot experience levels ranged from 300 to 2500 total flying hours with a median of 1400 total hours and 675 F-15 hours.

5 Results

5.1 Team exercises

The offensive and defensive counterair missions were designed to emphasize beyond-visual-range air-to-air combat tasks; *e.g.*, radar searching, sorting, targeting, weapons employment, communication, tactics, and mutual support. However, pilots uniformly reported that they experienced significant difficulties in completing their missions due to problems with the visual displays. Both the Dome and the DART received high praise for depicting the terrain and horizon. This information was used for judging attitude or for low-altitude flight when necessary. Difficulties were primarily experienced in seeing other aircraft. An instantaneous field of regard of less than 180° prevented pilots from maintaining tactical formation as they normally do in the aircraft, *i.e.*, at 3 or 9 o'clock. The AOI in the Dome received particular criticism. A pilot in the Dome could not see his wingman in tactical formation using either peripheral vision or a quick saccade left or right. The pilot in the Dome had to turn his head 90° and spend a second or two looking for his wingman. DART pilots experienced less difficulty in maintaining tactical formation within 1.8 km (1 nmi). Problems with field of view also prevented pilots from providing mutual support while engaged with enemy aircraft.

Pilots described their ability to resolve an air target as related to a lack of visual acuity, which is a function of display luminance, contrast, and resolution, plus the level of detail in the computer-generated aircraft model. The level of detail varied with range from the eyepoint. The major problem caused by lack of acuity was inability to determine the aspects of other aircraft. Pilots could not

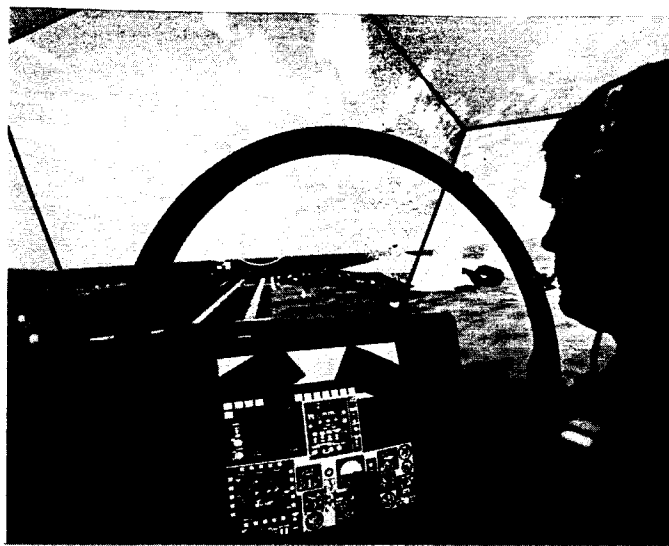


FIGURE 4 — Pilot and cockpit inside DART.

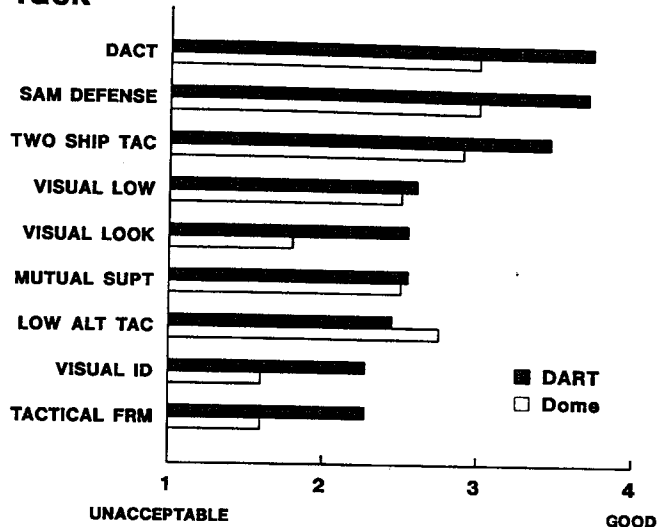
determine in which direction other aircraft were heading without watching their target's flight path for several seconds. Pilots also reported that they could not maintain tactical formation beyond 0.9–1.8 km (0.5–1.0 nmi) without using many additional radio calls due to inability to judge aspect. In addition, pilots could not visually determine distance from other aircraft at low levels of detail. Acuity problems also plagued pilots at the merge where the F-15 passes an enemy aircraft at high speed. When a pilot could visually locate the threat aircraft or his wingman, he could not tell which way the other aircraft were going quickly enough to take a tactical advantage. Overall, both DART and Dome pilots reported that visual flying was difficult and that they learned to use nighttime tactics and detached mutual support.

At the end of each week, pilots were asked to rate the value of the training received using the Multirad system for each of 30 flight tasks on a scale from 1=Unacceptable to 5=Excellent. Multirad training was rated highest for nonvisual tasks, notably operation against multiple enemy aircraft and practice working with an air weapons controller. Among the visual tasks, Multirad training was rated highest for dissimilar air-combat training and defense against SAMs. Mean ratings for the DART and Dome are shown in Fig. 5. The tasks are coded: DACT – dissimilar air-combat training; SAM DEFENSE – defense against surface-to-air missiles; TWO SHIP TAC – two-ship tactics; VISUAL LOW – visual low-altitude flight; VISUAL LOOK – visual lookout; MUTUAL SUPT – mutual support; LOW ALT TAC – low-altitude tactics; VISUAL ID – visual identification of target aircraft; TACTICAL FRM – tactical formation. Differences in ratings between the two displays are not statistically significant.

5.2 Dome vs. DART exercises

Twelve pilots participated in the DART vs. Dome exercises. Aircraft were initialized facing each other 18 km (10 nmi) apart. Pilots were instructed to fly towards each other and turn to engage as they passed. After three setups, pilots traded cockpits and flew three more. At the pilots' request, the more-successful pilots flew against each other until an overall winner was determined. Overall, 36 out of 55 engagements (65%) were won by the pilot flying in the DART.

Task



Rating of Multirad Training

FIGURE 5 — Mean ratings of Multirad training for nine tasks.

6 Conclusions

Pilots participating in TRUE rated the training received as highly valuable, particularly for beyond-visual-range tasks which emphasized multiship operations. The major limitations on the value of the training resulted from the visual displays. While wide-field-of-view displays were rated by pilots as necessary for effective training, inadequacies in the visual display systems reduced pilot situation awareness and induced simulator-unique behaviors. Pilots could not maintain tactical formation or count on mutual visual support. Although the DART had poorer resolution than the Dome, pilots preferred it due to its greater contrast and larger instantaneous field of view. While their mission performance was often successful, pilots asserted that their tactics were sometimes different from aircraft tactics, leading to opportunities for negative transfer of training. Representative comments from TRUE pilots include, "We need two DARTs so we can keep sight of each other. With current systems we are developing simisms (*i.e.*, behavior patterns unique to the simulator, which will not transfer to the aircraft)," or "He who sees will have better SA (situation awareness)." The most telling comment was, "I would have died less if I could have seen more."

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