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JOINT VISUAL SYSTEM OPERATIONAL EVALUATION (JOINT VIS-EVAL) SITE 1

CAE ADVANCED FIBER-OPTIC HELMET MOUNTED DISPLAY

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The Joint Vis-Eval is a follow-on effort to evaluate additional visual display devices and a multi-service effort including Air Force, Navy and Marine pilots. The objective of the initial Joint Vis-Eval was to identify the capability and limitations of the latest generation of Advance Fiber-Optic Helmet Mounted Display (FOHMD) developed by CAE Electronics, Ltd. Purpose: (1) determine trainability of tactical mission tasks with available visual display technology, (2) demonstrate current visual simulation technology to users, (3) obtain feedback from those users to help define future visual requirements and (4) provide information and data to support future simulation acquisition decisions. A team of highly experienced F-15E, F-16C and FA-18C/D instructor pilots evaluated the Advanced FOHMD system using fighter tasks in a mission context. The United States Air Force Formal Training Unit (FTU) and United States Navy/United States Marine Corps Fleet Replacement Squadron (FRS) training levels were used as the benchmark for the evaluation. Each evaluator flew three missions: a familiarization and two evaluation missions. At the end of each mission, the pilot completed a questionnaire and debriefed the analysis team to document the task training capability of the display system. The Advanced FOHMD has several significant improvements over earlier versions of the FOHMD. These improvements include: (1) acceptable eye tracking, (2) improved resolution, (3) limited improvements in the area of in-cockpit viewing of instruments and controls and (4) a more effective high resolution inset. The results and discussion indicate that the Advanced FOHMD provides training capability for selected fighter tasks. Human factors issue needs to be addressed to improve pilot acceptability.

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ACRONYMS

A/A	Air-to-Air
ACC	Air Combat Command
ACM	Air Combat Maneuvering
AFB	Air Force Base
AFMC	Air Force Materiel Command
AFOHMD	Advanced Fiber Optic Helmet Mounted Display
AGL	Above Ground Level
AHC	Aircraft Handling Characteristics
AIM-9	Air Intercept Missile
AOI	Area-of-Interest
BFM	Basic Fighter Maneuvering
CAF	Combat Air Forces
CRT	Cathode Ray Tube
CT	Continuation Training
DB	Dive Bomb
Deg	Degrees
DMPI	Desired Munitions Point of Impact
DTOS	Dive Toss
EO	Electro-Optic
ESIG	Evans and Sutherland Image Generator
FFOR	Full Field Of Regard
FOHMD	Fiber-Optic Helmet Mounted Display
FOV	Field of View
FRS	Fleet Replacement Squadron
FTU	Formal Training Unit
HAS	High Angle Strafe
HD	High Angle Dive Bomb
HMD	Helmet Mounted Display
HUD	Head-Up Display
ID	Identification
IFR	Instrument Flight Rules
IG	Image Generator
IP	Instructor Pilot
IP	Initial Point
IR	Infrared
JAST	Joint Advanced Strike Technology
LAB	Low Angle Bomb
LALD	Low Angle Low Drag
LAN	Local Area Network
LAS	Low Angle Strafe
LAT	Low Altitude Training
LATS	Low Altitude Training System
LOD	Level of Detail

MFS	Manned Flight Simulator
NATC	Naval Air Test Center
NAWCAD	Naval Air Warfare Center Aircraft Division
NM	Nautical Miles
NR	Not Rated
OFT	Operational Flight Trainer
Pix	Pixels
R&D	Research and Development
RTB	Return to Base
RWR	Radar Warning Receiver
SA	Situation Awareness
SAM	Surface-to-Air Missile
SIF	Standard Interchange Format
TACAN	Tactical Air Navigation
Texels	Texture Elements
TSRA	Training System Requirements Analysis
USA	United States of America
USAFE	United States Air Force in Europe
UTD	Unit Training Device
VFR	Visual Flight Rules
VID	Visual Identification
VLD	Visual Lay Down
WFOV	Wide Field of View
WST	Weapon System Trainer

PREFACE

This report summarizes the findings of the joint visual system evaluation of the CAE Electronics Advanced Fiber-Optic Helmet Mounted Display (AFOHMD) located at the Manned Flight Simulator Facility, Naval Air Warfare Center, Aircraft Division, Patuxent River, MD. The effort was managed by the Training Systems Product Group, Aeronautical Systems Center, Wright-Patterson AFB, OH and funded jointly by the same and the Joint Strike Fighter Program Office, formerly Joint Advanced Strike Technology (JAST) Program. Evaluations were provided through arrangement with the Air Combat Command (ACC), Langley Air Force Base, VA and the Naval Air Systems Command, Arlington, VA. Lt. Col. Harry Daye was the Evaluation Team Chief and Mr. Jim Brown of the Training Systems Product Group was the Training Analyst and Lead Engineer. Support was received from Lt. David Street, Ph.D. of the Naval Air Systems Command, PMA 205 Training Systems Program Manager. There were eight evaluation pilots including four USAF, two USN, and two USMC. They averaged 2275 flying hours and almost 800 hours as Instructor Pilots (IP's). The Evaluation Team consisted of:

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MAJ Mike Cariello, USMC
MAJ John Ayres, USAF
LT Luther Hook, USN
CAPT Charles Midthun, USAF
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CAPT Mitch Reeves, USAF

The Training Systems Product Group extends special thanks to the Air Combat Command and the Naval Air Systems Command for supporting the effort and to the dedicated evaluators who gave so much of their time and effort to the project.

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EXECUTIVE SUMMARY

The Training Systems Product Group, ASC/YW, initiated a Training Systems Requirements Analysis (TSRA) in response to a March 1989 request from United States Air Forces Europe (USAFE) to investigate low altitude training needs for the 1990s. Recommendations made in 1991 based on that analysis, indicated that modern visual systems have the potential to significantly enhance available tactical aircraft training and may assist in slowing down the loss of critical low altitude flying skills that are not frequently practiced.

The Visual Evaluation Program (Vis Eval) was created in 1992 by ASC/YW to evaluate the adequacy of image display technology to support low altitude training. Its purpose was to (1) determine trainability of tactical mission tasks with available visual display technology, (2) demonstrate current visual simulation technology to users, (3) obtain feedback from those users to help define future visual requirements and (4) provide information and data to support future simulation acquisition decisions.

In 1993, ASC/YW, with the support of Air Combat Command (ACC), conducted the first Vis-Eval. In this report, we refer to it as Vis-Eval I. Vis-Eval I included evaluation of three different types of wide field-of-view visual display systems which had the potential to meet tactical mission training needs.

Joint Vis-Eval is a follow-on effort to evaluate additional visual display devices. It was a collaborative effort between ASC/YW, NAVAIR (PMA-205), and the JAST Program Office. It was therefore modified to be a multi-service effort and included Air Force, Navy and Marine Corps pilots. In addition, the evaluation process has been restructured to take advantage of lessons learned during Vis-Eval I.

The objective of the initial Joint Vis-Eval was to identify the capability and limitations of the latest generation of Advanced Fiber Optic Helmet Mounted Display (FOHMD) developed by CAE Electronics, Ltd. An earlier version of this type of display was evaluated as part of Vis-Eval I at CAE Electronics GmbH, Stolberg, Germany in 1993. The results of this evaluation were reported in Visual System Operational Evaluation, Final Report, Document No. ASC-TR-94-5030, dated 31 July 1994. Modifications by CAE, prompted by earlier evaluations, are included in the device at the NAWCAD, Patuxent River, MD.

A team of highly experienced F-15E, F-16C and FA-18C/D instructor pilots evaluated the Advanced FOHMD display system, using fighter tasks in a mission context. USAF Formal Training Unit (FTU) and USN/USMC Fleet Replacement Squadron (FRS) training levels were used as the benchmark for the evaluation. Each evaluator flew three missions, a familiarization and two evaluation missions. At the end of each mission, the pilot completed a questionnaire and debriefed the analysis team to document the task training capability of the display system.

The results of the AFOHMD Joint Vis-Eval are presented in this report in detail. Major conclusions are summarized below:

The AFOHMD has several significant improvements over earlier versions of the FOHMD. These improvements include: (1) acceptable eye tracking, (2) improved resolution, (3) limited improvements in the area of in cockpit viewing of instruments and controls and (4) a more effective high resolution inset. These changes have facilitated performing most single aircraft tasks and several important multiple aircraft tasks. Nine of the eleven single aircraft tasks evaluated by the team were rated trainable (Figure 3-1). Five of the twenty multiple aircraft tasks evaluated by the team were rated trainable (Figure 3-2).

Human Factors problems with the AFOHMD make it currently unacceptable for USAF FTU and USN/USMC FRS training. Problems included: (1) the helmet slips causing loss of imagery when attempting to look aft of the 3-9 line, (2) the helmet is heavy and uncomfortable, (3) fiber-optic bundles catch on the display structure, (4) it is difficult for the pilot to view instruments and controls in the cockpit due to interference with the pilot's vision by the helmet optics and (5) the cockpit is dark during a daylight scene.

The AFOHMD requires significant human factors improvements before it could be considered acceptable for training.

SECTION 1 - INTRODUCTION

1.1 BACKGROUND

1.1.1 Ground-based simulator training for tactical fighter aircrews is limited by lack of adequate visual display systems. Efforts to develop visual systems with the capability to provide useful tactics training have met with limited success. A major requirement of tactical visual systems is that the display must have a large, instantaneous field-of-view (FOV) both horizontally and vertically and a field-of-regard (FOR) limited only by the aircraft structure. This requirement has been difficult for industry to meet while still providing resolution and brightness that is adequate to realistically train tactical flying tasks. Other visual system constraints have been evident in the area of data base size and detail. Fighter aircraft rapidly traverse long ranges in a very short time spans. These large distances and high speeds place major burdens on data base development and image generation. Fighters also operate at altitudes ranging from the surface to 40,000 feet. Fighter pilots are required to recognize objects such as another F-16 or F-18 at realistic tactical ranges, assess the range and closure aspect of another aircraft, and fly tactical formation. They must also accurately identify ground objects such as vehicles, roads and bridges. This wide range of requirements has made it difficult for industry to develop display systems which meet the full range of fighter training requirements.

1.1.2 In the past, the Air Force has conducted operational evaluations to determine if advances in visual system technology could provide the capability to train tactical flying tasks. Among these efforts were Project 2235, Air-to-Ground Visual Simulation Demonstration (1976), Simulator Systems Comparative Evaluations (1977, 1979) and the F-15 Limited Field of View Visual System Training Effectiveness Evaluation (1984). The general findings of these efforts indicated that existing visual systems could train some, but not all, critical tactical flying tasks.

1.1.3 In March 1989, the United States Air Forces In Europe (USAFE) requested assistance from Air Force Systems Command (AFSC) in determining ways to meet its low altitude training needs for the 1990s. USAFE aircrews were limited to training at altitudes of no less than 250 feet and at airspeeds of no more than 475-550 knots. A training systems requirements analysis (TSRA) was conducted for the F-16C and F-15E weapon systems. Based on the analysis, recommendations indicated that modern visual systems had the potential to significantly enhance available tactical aircraft training and could assist in slowing down the loss of critical low altitude flying skills that are not frequently practiced due to range or safety constraints. To verify adequacy of image display technology to support low altitude training, an operational evaluation using aircrews was suggested.

1.1.3.1 As a result, ASC/YW, together with the support of Air Combat Command, conducted what has been referred to and reported as Visual System Operational Evaluation or Vis-Eval. We refer to the first Vis-Eval as Vis-Eval I in this report. Vis-Eval I included: Site #1, a Two Channel Area of Interest Dome Display, developed by Evans and Sutherland and conducted at the manufacturer's plant in Salt Lake City, UT; Site #2, the Display for Advanced Research and Training (DART), conducted on site at Armstrong Labs, Williams Gateway Airport, AZ and Site #3, the Fiber-Optic Helmet Mounted Display (FOHMD), developed by CAE Electronics, Ltd., Montreal, Canada, and conducted at CAE Stolberg, Germany. The results of these evaluations are reported in ASC-TR-94-5030, July 1994.

1.1.4 Display technology has improved since Vis-Eval I and these improvements must be evaluated for possible application to new visual system requirements. Joint Vis-Eval is a follow-on effort to evaluate improved and additional devices. Joint Vis-Eval differs from Vis-Eval I in several ways. It is now a multi-service effort including Air Force, Navy and Marine pilots and jointly funded by the Joint Advanced Strike Technology (JAST) Program and ASC/YW. The evaluation process has also been restructured to take advantage of lessons learned during Vis-Eval I.

1.2 AREAS TO BE INVESTIGATED: A visual system in its most elemental form, is comprised of the combination of a data base, an image generator (IG) and visual display system. This evaluation, similar to Vis-Eval I, focused on display systems.

1.3 PURPOSE: The purpose of this effort was to continue to operationally evaluate available visual image display technology for potential application to operational training of tactical fighter aircrews.

1.4 SCOPE AND LIMITING FACTORS: The evaluation was conducted at the Manned Flight Simulator (MFS) located at NAWCAD, Patuxent River, MD from 24 July through 2 August 1995. This evaluation consisted of two activities. The first activity was the operational evaluation and second was the engineering review of the system.

1.4.1 Operational Evaluation

1.4.1.1 The operational evaluation used an evaluation team comprised of eight instructor pilots, (four USAF, two USN and two USMC) with current FA-18, F-16C or F-15E experience.

1.4.1.2 The focus of this operational evaluation was to evaluate the training capability of the AFOHMD to support USAF Formal Training Units (FTU) and USN/USMC Fleet Replacement Squadrons (FRS). It was not structured as an experimental comparison. Instead aircrews were asked to rate the training capability of the visual display system under evaluation. Due to large differences in weapon system components and performance capability, it is not possible to compare one visual system to another. Rather, the intent of this evaluation was to rate the capability of the AFOHMD to support training of tactical mission tasks.

1.4.1.3 Even though visual displays were the focus of the evaluation, it was recognized that cockpit differences, image generation and data base capabilities impacted training capability ratings. Only subjective aircrew data was gathered during the operational evaluation. Objective data such as bombing scores, hits, etc., was not available. Engineering data was furnished by the site organization and development contractor and was verified by evaluation team engineering personnel. Operational reliability and maintainability issues were not evaluated although general availability of systems was noted.

1.4.2 Engineering Review

1.4.2.1 An engineering data review for this device configuration was conducted to verify the current visual systems display and image generator attributes (Annex H).

1.5 SPECIFIC OBJECTIVES

1.5.1 Objective 1. Evaluate the capability of selected image display technologies to support training of the tactical mission tasks (Annex B).

1.5.2 Objective 2. Baseline and document the engineering attributes for the simulator configuration. Emphasis is placed on the visual display, image generator and database at the time of the evaluation.

SECTION 2 - METHOD OF ACCOMPLISHMENT

2.1 METHOD OF TEST

2.1.1 Operational Evaluators. Eight pilots were selected for this evaluation including four Air Force, two Navy and two Marine pilots. All pilots had extensive fighter and fighter instructor pilot experience in the F-15, F-16 or FA-18 with one of the pilots having combat experience. Both Marine pilots were Top Gun graduates and one is currently an instructor at the school. The average flying time for the pilots was 2275 hours; average instructor time was 788 hours.

2.1.2 Training for Evaluators. Training for the team was provided in visual system technology and the evaluation process at the Flight Dynamics Laboratory Simulation Facility at Wright Patterson AFB, OH. Classroom instruction and demonstration training on visual system technology were given to evaluation pilots for recognition of visual features related to visual displays, visual image generation and databases. This training enabled the evaluators to better converse during the debrief on technical issues, to assess the inter-relationship of visual system components and to focus on visual displays for training capability ratings.

2.1.3 Operational Procedure. The evaluation was conducted over a two week period. A familiarization mission and two generic tactical evaluation missions were developed to permit the pilot to evaluate each of 11 single aircraft and 20 multiple aircraft tasks. Most tasks were further divided into a series of subtasks. The tasks, sub tasks, missions and mission events were developed by the Joint Vis-Eval Pilot Team during an initial meeting six weeks prior to the evaluation and were approved by the Evaluation Team Chief. A complete list of tasks and subtasks is located in Annex B. Not all tasks and subtasks were flown on each mission, but the missions were structured to cover each task and subtask at least once during the evaluation. The Familiarization Mission was structured to orient pilots to the FA-18 and the visual system as well as to overcome "first impressions". Each evaluation mission consisted of a set of events (air to surface, air to air, formation, threat reaction, etc.) to evaluate the tasks in a mission context. Mission events increased in complexity from single aircraft events in the beginning of Mission 1 to complex multi aircraft events later in Mission 1 and in Mission 2. The multiple aircraft events were flown as a two aircraft element against various air and ground threats.

2.1.3.1 Before the evaluation, two of the evaluation team pilots developed four low level routes to be used during the evaluation. The day before the arrival of the first pilot team, the Team Chief and supporting personnel evaluated the systems at the Manned Flight Simulator to finalize the conduct of the evaluation.

2.1.3.2 Upon arrival, each pilot had a helmet liner poured and fitted to a helmet so that the AFOHMD would not slip on the pilot's head. This process required approximately two hours. Prior to first flight, an additional period of approximately 30 minutes was required for initial mounting of the display to the pilot's helmet and adjusting the optical display for each pilot. Each pilot team was then in-briefed on facilities, procedures and schedule of events. Pilots were organized into four teams, each with one USAF and one USN or USMC pilot. The multi-service teams were devised to better integrate the results of the evaluation.

2.1.3.3 Team members briefed and flew each mission as a two aircraft flight, one pilot in the cockpit wearing the AFOHMD and one at the Mini Crew Station (see para 2.3.1.5) flying the second aircraft. They then reversed roles to repeat the mission. After each mission, pilots individually rated each task and subtask using the rating scale shown in Annex E and filled out the questionnaire shown in Annex F. Additionally, an individual debriefing was conducted to discuss the ratings and comments. All debriefings were recorded on tape for additional reference.

2.1.4 Engineering Review. Engineering data were requested and discussions held with both site personnel and the visual system contractor. Observations of system performance were made and noted for further discussion. During the evaluation, available data were analyzed and any requirements for additional data identified. A detailed hardware description is presented in Annex H.

2.2 METHOD OF EVALUATION

2.2.1 Operational Evaluation. Two criteria were used to evaluate the AFOHMD. The measures of effectiveness were the evaluation pilot subjective ratings in accordance with Annex E criteria and the evaluation team's assessment of the capability of each system to train pilots in an operational training environment. The criteria were that at least eighty per cent of the ratings for the task must receive a score of three or higher (first criterion) or the task must receive an overall acceptable assessment by the evaluation team (second criterion).

2.2.2 Engineering Description. The intent of the engineering evaluation was to document visual system performance as it existed at the time of the operational evaluation. Many problems which existed with the system were reviewed and potential improvements to the system are discussed in this report.

2.3 SYSTEMS ENGINEERING DESCRIPTIONS

2.3.1 Advanced Fiber-Optic Helmet Mounted Display (AFOHMD) and MAXVUE ™ Image Generator. A detailed description of the visual system performance characteristics is presented in Annex H.

2.3.1.1 Evaluation Cockpit and Aircraft Simulation. The evaluation cockpit was a fixed base F/A-18A cockpit and HUD modified to represent an FA-18C for use in systems development and engineering flight test for the NAWCAD and the Naval Air Test Center (NATC). The displays and controls, except for the HUD optics, replicated the controls and displays of the FA-18C. Radar and weapons delivery system simulations were limited and did not simulate weapon release, weapon flyout or weapon impact. Flight performance of the simulated aircraft was representative of the FA-18C. The "roll in/roll out" cockpit was shared with other visual display systems and was moved into a dome display when not used for this evaluation. When used for this evaluation, the cockpit was rolled into place under the frame supporting the AFOHMD projectors, fiber optics, displays and helmet position sensor.

2.3.1.2 Image Display. The AFOHMD is a new generation FOHMD display which includes modifications over earlier generations. Modifications include (1) an occulometer which improves eye tracking, (2) more eye relief in the display optics which permits the pilot to better see in the cockpit to locate instruments and controls and (3) a high resolution inset which is almost unnoticeable to the viewer. Also, the display uses two high resolution CRT projectors in place of four light valve projectors used in earlier models.

2.3.1.3 Image Generation. A CAE Electronics MAXVUE ™ provided image generation for the evaluation. This IG has four channels and a post processor which combines a background channel with a high resolution inset channel for each eye.

2.3.1.4 Database. The database used in the evaluation was a subset of the AV-8B West Coast Database.

2.3.1.5 Mini Crew Station Console. The Mini Crew Station consisted of a console with a CRT displaying simulated aircraft instruments, two throttles, a side stick controller, a keyboard and a three monitor display above the instrument CRT providing an out-the-window visual display. For the first two pilot teams, an ESIG 2000 IG provided a database, for horizon reference only, that was not correlated in location or altitude with the database seen in the evaluation cockpit. On Saturday of the first week, the Mini Crew Station IG was changed to a CompuScene IV/A with an AV-8B database fully correlated with that seen in the evaluation cockpit. This was the only system change made during the evaluation. Above the console was an additional monitor displaying the evaluation cockpit HUD display. An additional blackboard sized display provided a dynamic plan view of the selected low level route and all aircraft involved. Accurate range to the other aircraft was available only from a separate visual system control console. The Mini Crew Station console provided an FA-18A flight simulation but was designed to be used to control a flyable target, not to control another aircraft in a formation or to provide training. For this evaluation, one of the team pilots used this console to provide the other aircraft for all multiple aircraft tasks including tactical and close formation (both lead and wing) as well as Basic Fighter Maneuvering (BFM) and Air Combat Maneuvering (ACM).

SECTION 3 - RESULTS AND DISCUSSION

3.1 MISSION AND ENGINEERING PERFORMANCE

3.1.1 TRAINING MISSION PERFORMANCE

The first objective of this evaluation was to determine the capability of the AFOHMD visual display to support training of the evaluation tasks described in Annex B. The operational evaluation was conducted as discussed in para 2.2.1. The evaluation criteria are presented in Annex E. Results and discussion follow:

3.1.1.1 Tasks Evaluated. All of the 12 single aircraft and 20 multiple aircraft tasks originally identified in Annex B, except 1.4.2, Night Landing, were evaluated during the missions flown. Night Landing could not be evaluated because the MAXVUE's ™ night scene was not integrated at the MFS.

3.1.1.2 Results and Discussion. The AFOHMD was evaluated as being able to support FTU/FRS training for 9 of the remaining 11 single aircraft and 5 of 20 multiple aircraft tasks. The composite ratings for all single and multiple aircraft tasks are shown in Figures 3-1 and 3-2. Annex G lists the ratings for each task and subtask by pilot team as well as the composite rating by the full evaluation team. Significant pilot comments for each task, and sub task where appropriate, are addressed below.

3.1.1.2.1 A significant improvement in acceptable ratings for multiple aircraft tasks and subtasks occurred between Teams 1 & 2 and Teams 3 & 4. As discussed in paragraph 2.3.1.5, a change was made to the Mini Crew Station between the evaluation by the first two pilot teams and the evaluation by the second two teams. Initially, the Mini Crew Station out-the-window visual display displayed a database uncorrelated in position and altitude with the database displayed in the evaluation cockpit. After the change, the Mini Crew Station database, in position and altitude, was fully correlated with the evaluation cockpit. No changes were made to the AFOHMD, the evaluation cockpit, or evaluation cockpit simulation. To contrast the results, Teams 1 & 2 rated 4 multiple aircraft tasks as acceptable while Teams 3 & 4 rated 16 multiple aircraft tasks as acceptable. Annex G lists the ratings for each task and subtask by pilot team as well as the composite rating by the full evaluation team. The improvement in the multiple aircraft task ratings may be the result of providing correlated and consistent references to both pilots enhancing their ability to operate as a flight of two aircraft. It could also be a result of the ease with which individual pilots became teams. However, since none of the pilot teams evaluated the system both before and after the change, the reason for the change can only be inferred, not proven. The possible impact of this supporting system to the pilots' evaluation of the simulation stresses the importance of analyzing the training system as a whole versus focusing on a single subsystem.

3.1.1.2.2 Single Aircraft Tasks. Discussion of each task follows.

3.1.1.2.2.1 Low Level. Met acceptable training criteria.

Positive comments include:

- Good ground rush, good line of sight.
- Imagery is good at 500 feet and below.
- Depth perception cues for altitude and cues for airspeed are acceptable.

Negative comments include:

- Blurry spots would consistently appear in the 500 - 1500 foot regime.
- Rate of speed sensation across the ground seems to step in increments instead of accelerating smoothly.
- Additional cues over water such as white caps would help depth perception.

3.1.1.2.2.1.1 Navigation. Met acceptable training criteria.

Positive comments include:

- Could adequately identify physical features during navigation.
- Able to navigate well using visual system with available data base.
- Ridges, trees, buildings, etc. clear and detailed at low to medium altitudes.

Negative comments include:

- Impossible to focus on any one specific point, better to scan.
- Aircraft system comment - correlation between database and avionics was off.

3.1.1.2.2.1.2 Low Altitude Training. Met acceptable training criteria.

Positive comments include:

- Could easily train in low level tactics (LAT/NAV/SCAT) using this system.
- Ridge line crossings are pretty realistic. (Better in the desert than in the forest because of contrast between trees and ground).
- Ground rush comparable to the real thing.

3.1.1.2.2.1.3 Detect/ID Ground Threat. Did not meet acceptable training criteria. The pilot must be able to acquire the threat, determine if it is tracking his aircraft or flight, and identify the threat to take appropriate defensive action.

Negative comments include:

- Minimal to no capability to detect ground threats.
- If ground threat is detected, it appears as a white dot that is not distinguishable from an aircraft. No chance for identification. Put smoke trails on missiles to improve acquisition.
- SAMs would fly through the ground.

3.1.1.2.2.2 Medium Altitude Maneuvering. Met acceptable training criteria.

Positive comments include:

Contrast and brightness good.
Range, rate, aspect all good.
Good system cues. No problem with orientation.

Negative comments include:

Mountain ranges popped into view instead of smoothly blending into the scene (IG/database problem).

The abrupt disappearance of vertical development as the aircraft climbs detracted from the realism (IG/database problem).

Other aircraft looked the same at three miles as at eight miles. Expect to see an FA-18 at 8-10 NM.

3.1.1.2.2.3 Visual Weapons Delivery. Met acceptable training criteria.

Positive comments include:

Good bombing simulation. Necessary cues provided for good training.
Target/IP ID from all altitudes is possible.
Once a target is visually ID'd, attacks and reattacks easily simulated.

Negative comments include:

Basic simulator comment - weapons delivery systems simulation shortcomings detracted from the evaluation.

3.1.1.2.2.3.1 Low Altitude. Met acceptable training criteria.

Positive comments include:

Low altitude weapons delivery OK.
Able to adequately see targets and cross-check freely between HUD, instruments and target area.

Negative comments include:

For Visual Lay Down, very difficult to identify targets at sufficient distance to allow corrections to be made to get bombs on target.

Ground speed and height cues conspicuously absent. Low density in the database, few vertical objects and poor texturing contributed to this problem.

Basic simulator comment - HUD bomb symbology shifting around and showed incorrect release cues.

3.1.1.2.2.3.2 High Altitude. Did not meet acceptable training criteria.

Negative comments include:

Specific designated mean point of impact (DMPI) hard to pick out.

Altitude perception was noticeably different from actual altitude - always below minimum altitude for release.

Lack of resolution/acuity made target ID difficult resulting in later identification than in aircraft. Late target identification results in late aim point correction increasing delivery error.

Basic simulation comment - the various A/G modes were not accurate and showed incorrect release cues.

3.1.1.2.2.4 Approach/Landing. Met acceptable training criteria. (See comments under day conditions, next paragraph.)

3.1.1.2.2.4.1 Day. Met acceptable training criteria.

Positive comments include:

Good simulation for daytime operations for both straight in and overhead patterns.

Contrast and brightness good.

Good visibility restriction for daytime.

Good simulation of IMC conditions.

System is much more effective as a trainer when overhead pattern flown above 1000 feet.

Negative comments include:

The sensation of being higher than actual altitude during final approach was consistently apparent. This resulted in a tendency to drag in approaches.

Difficult to judge lateral offset from runway.

Approaching initial at approximately 3 NM, runway "jumped" into view.

Unable to locate carrier until descended to low altitude.

3.1.1.2.2.4.2 Night. Night Landing could not be evaluated because the night scene was not integrated in the MAXVUE ™ IG at the MFS.

3.1.1.2.2.5 General Situation Awareness. Met acceptable training criteria.

Positive comments include:

Excellent.

Overall good.

Negative comments include:

With rapid head movements, the visual display jittered which was very annoying. Smooth, slow head movements did not seem to cause a problem.

Restrictions to head movement detracted from normal head-eye correlated movement.

Lack of full field of view detracted from overall SA. However, there was sufficient field of view to be usable as a trainer. A forced head scan pattern was required to build SA.

Peripheral vision less than desired.

3.1.1.2.3 Multiple Aircraft Tasks.

3.1.1.2.3.1 Basic Tasks. Did not meet acceptable training criteria. Although the task met the 80% acceptable rating (Criterion 1), the team rated the task unacceptable (Criterion 2) due to the failure to meet criteria for close formation, ranging exercises and air-to-air exercises.

3.1.1.2.3.1.1 Close Formation/Formation Rejoin. Did not meet acceptable training criteria.

Positive comments include:

- Formation flying is excellent.
- Formation flying is very realistic with closure rate the weakest cue.
- Can't fly close (parade) formation, but that's true of almost all simulators. Route or cruise formation was fine.
- Good visual representation of aircraft references.

Negative comments include:

- In close formation, the displayed image jumps fore and aft as well as vertically (10-20 feet).
- Flying close formation is difficult, but not impossible, due to lack of aircraft visual cues for closure.
- Limited ability to fly close formation due to IOS-simulator interface.

3.1.1.2.3.1.2 Weapon System Checks. Met acceptable training criteria.

Positive comments include:

- Weapon system check training good.

3.1.1.2.3.1.3 Ranging Exercises. Did not meet acceptable training criteria.

Positive comments include:

- Ranging exercises OK - size of other aircraft seemed realistic.

Negative comments include:

- Difficult to determine range, closure and aspect beyond 3000 foot range.
- Ranging drill required to calibrate for aircraft sizes in simulator as they differ from real life.
- Visual acuity (resolution) was less than desired in most phases.
- Helmet/fiber optic cables make turning your head aft of the 4/8 o'clock position very difficult. The opposite side display becomes shadowed as you reach the aft limits of FOV.
- Limits to rearward visibility did not allow for good defensive ranging. Bogeys aft of 4/8 o'clock nearly impossible to acquire.
- Brightness was the same for the target and the area just above the horizon causing the target to disappear when approaching the horizon.
- Ranging difficult - team became reasonably accurate at 9000 feet and less, but I think it was because of the high experience level of the team.

3.1.1.2.3.1.4 Air-to-Air Exercises. Did not meet acceptable training criteria. The ratings changed markedly between the first week (29 % acceptable) and the second week (100 % acceptable). The difference appears to be related to the improved ability to set up and control the exercise after the change was made to the Mini Crew Station.

Negative comments include:

Closure sometimes difficult to tell until within a mile.

Late recognition of aspect angle occurred on heat to guns and snapshot exercises.

Visual acuity (resolution) is biggest problem. Difficult to determine range, closure, aspect until inside 3000 feet.

3.1.1.2.3.2 Tactical Formation. Did not meet acceptable training criteria but all ratings for this area improved markedly for the second week. Acceptable ratings the first week ranged from 17 to 29 % while acceptable ratings the second week were all 100 %. Much of the difference appears to be due to the improved ability to control the other aircraft from the Mini Crew Station.

Positive comments include:

Wing flashes from 1.5 NM separation are easily seen.

Closure rate and aspect angle determination better at closer ranges but overall very realistic.

Negative comments include:

Difficult to set good range parameters.

Basic formation keeping was very difficult unless headings were called out over the radio, but can be done with difficulty.

Could not see visual signals to initiate/stop turn.

A little difficult to tell aspect and closure outside of approximately 2.5 - 3 NM.

Difficult at ranges beyond 8000 feet due to lack of resolution, acuity and model/background contrast at horizon. Tactical formation in the aircraft requires ranges from 3,000 to 12,000 feet.

Outside 8000 ft, difficult to determine range/aspect since aircraft becomes a white blob and appearance/size doesn't change.

Display would blank looking at 3 or 9 o'clock.

3.1.1.2.3.2.1 Medium Altitude. Did not meet acceptable training criteria. (For basic comments see Tactical Formation, previous paragraph.)

Positive comments include:

Cues OK at longer ranges inside 6000 feet with good visual signals and cues inside 3000 feet.

Negative comments include:

Unable to determine visual signals (wing flashes, etc) but can estimate range within 3000 feet and can see line of sight.

Loss of visual display with rapid head movements.

3.1.1.2.3.2.2 Low Altitude. Did not meet acceptable training criteria. (For basic comments see Tactical Formation, previous paragraph.)

Negative comments include:

Too much time required looking at lead and not looking at terrain to avoid missing signals and to stay in position.

Difficult. Other aircraft disappeared while flying at low altitude.

3.1.1.2.3.3 Threat Reaction. Did not meet acceptable training criteria.

Negative comments include:

Threat reactions difficult due to helmet restrictions on head movement.

3.1.1.2.3.3.1 Air-to-Air. Did not meet acceptable training criteria. (See basic comment under Threat Reaction, previous paragraph.)

Negative comments include:

Adequate cues not present to acquire threat in either air-to-air or surface-to-air regimes.

Basic simulation comment - air-to-air bandits slow to react to console inputs, flown below tactical airspeeds.

3.1.1.2.3.3.2 Surface-to-Air. Did not meet acceptable training criteria. (See basic comment under Threat Reaction, previous paragraph.)

Negative comments include:

Difficult to pick up simulated missiles in flight except between 10 and 2 o'clock position.

Adequate cues not present to acquire SAMs. Ground flash at launch and smoke trail would help.

Threats require in cockpit cues such as RWR to provide warning of the threat.

3.1.1.2.3.4 Visual Weapons Delivery. Met acceptable training criteria. Although the task did not meet the 80% composite acceptable rating (Criterion 1), the team rated the task acceptable (Criterion 2). Acceptable ratings for this task area improved markedly the second week with the exception of High Angle Dive Bomb.

Positive comments include:

All attacks flown within approximately 3 NM of the other aircraft were easily flown and we were able to maintain mutual support.

Visual system adequate to accomplish task and regain mutual support from both echelon/split attacks and wheel patterns.

Negative comments include:

System not able to support echelon attacks due to its poor ability to display aspect and closure.

Due to bulky headgear, difficult to keep visual contact with wingman/leader and also look at target (also due to peripheral vision limitations).

Tactical formation difficult due to not being able to see action signal (needs to be called on radio).

3.1.1.2.3.4.1 Target ID (IP/Target/Reattack). Met acceptable training criteria.

Negative comments include:

Targets "pop" into FOV making visual reattacks sometimes difficult.

3.1.1.2.3.4.2 Low Altitude. Met acceptable training criteria. Although the task did not meet the 80% acceptable composite rating (Criterion 1), the team rated the task acceptable (Criterion 2). (See basic comments under Visual Weapons Delivery.)

Positive comments include:

In 3000 foot line abreast formation, able to do simultaneous roll in/attacks and maintain mutual support.

3.1.1.2.3.4.3 High Altitude. Did not meet acceptable training criteria. (See basic comments under Visual Weapons Delivery.)

Negative comments include:

Depth perception is off when above several thousand feet.

Required depth perception and ground rush cues missing in high altitude bomb.

High altitude target identification occurs late due to resolution/acuity.

3.1.1.2.3.5 Air-to-Air Tasks. Did not meet acceptable training criteria. Although the task met the 80% acceptable rating (Criterion 1), the team rated the task unacceptable because the most important tasks of BFM and ACM did not meet acceptable training criteria (Criterion 2).

Negative comments include:

Tally Ho acquired too far away. The target would pop out at you as a bright light.

Forward quarter Tally Ho was difficult until approximately 1.5 NM.

Tally Ho/ID much later due to contrast of targets presented.

Visual identifications (VIDs) difficult, usually occurring at less than 2000 feet.

Basic simulation comments - no feedback for weapons employment. The aircraft HUD was not accurately correlated to the selected weapons and the radar did not track the bandit in the HUD correctly.

3.1.1.2.3.5.1 Intercepts. Intercepts are structured setups requiring limited maneuvering and relying primarily upon the radar except for Tally Ho/VID prior to weapons employment. Met acceptable training criteria.

Negative comments include:

Basic Simulation - needed to do a foresight prior to the mission.

Due to a misalignment, radar didn't work properly.

Aircraft HUD was not accurately correlated to the selected weapons.

3.1.1.2.3.5.2 Basic Fighter Maneuvering. The high dynamic rates of movement between aircraft and the resulting large and rapid movements of the pilot's line of sight surfaced limitations of the FOHMD as implemented for the evaluation. Did not meet acceptable training criteria.

Positive comments include:

Altitude cueing when conducting BFM was very good.

The BFM training aspect is very good, can teach the finer points.

Once you start close maneuvering (inside 7000 feet), thought the aircraft graphics were some of the best I've seen. Would be very usable to train students/fleet aviators alike.

Negative comments include:

The display is unacceptable for BFM and ACM.

Helmet is awkward. Looking aft of 3/9 o'clock is most difficult, with visual displays fading out and helmet getting hung up on fiber optic cables and overhead structure.

The helmet restricts head movement and, when rapidly moved, jitters to the point of being disorienting. The cables on the helmet also pull it left and right when the head is rotated through large angles causing eye tracking problems.

Visual acuity does not allow for adequate assessment of changing aspect in time to react as in the aircraft. Not able to see planform (aspect) or nose rate until inside 7000 feet.

No visual simulation for weapons employment.

3.1.1.2.3.5.3 Air Combat Maneuvering. The high dynamic rates of movement between aircraft and the resulting large and rapid movements of the pilot's line of sight surfaced limitations of the FOHMD as implemented for the evaluation. Did not meet acceptable training criteria.

Positive comments include:

Good to fly formation, predict range, deploy and enter merge area but visual not supportive of 2 v X maneuvering at merge.

Visual system supports ACM basics.

Negative comments include:

The display is unacceptable for BFM and ACM.

Helmet is awkward. Looking aft of 3/9 o'clock is most difficult, with visual displays fading out and helmet getting hung up on fiber optic cables and overhead structure.

The helmet restricts head movement and when rapidly moved, jitters to the point of being disorienting. The cables on the helmet also pull it left and right when the head is rotated through large angles causing eye tracking problems.

Visual acuity does not allow for adequate assessment of changing aspect in time to react as in the aircraft.

Very difficult to maintain formation.

Not able to see planform (aspect) or nose rate until inside 7000 feet.

No visual simulation for weapons employment.

3.1.1.2.3.6 General Situation Awareness. Met acceptable training criteria.

Positive comments include:

General SA high due to very detailed and clear visual display.

Negative comments include:

Weight of helmet and helmet restrictions to head movement detract from SA.

Instantaneous FOV still limits SA but not to the point it can't be maintained with head scan.

Displays jitter with rapid head movements causing the pilots SA to go down.

Single aircraft SA much better than multiple aircraft SA.

SINGLE AIRCRAFT

% of Tasks Rated 3 or Higher	Composite
Low Level	100
Navigation	100
Low Altitude Training	100
Detect/ID Ground Threat	31
Medium Altitude Maneuvering	83
Visual Weapons Delivery	100
Low Altitude	100
High Altitude	79
Approach/Landing	100
Day	100
Night	NR
General Situation Awareness	100

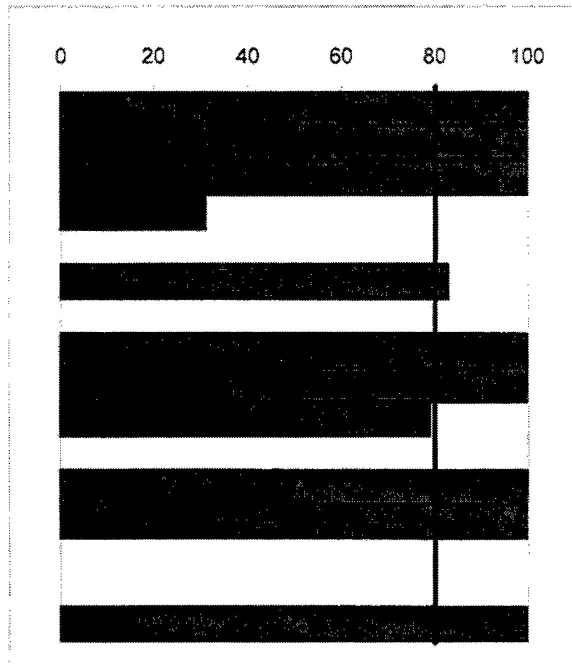
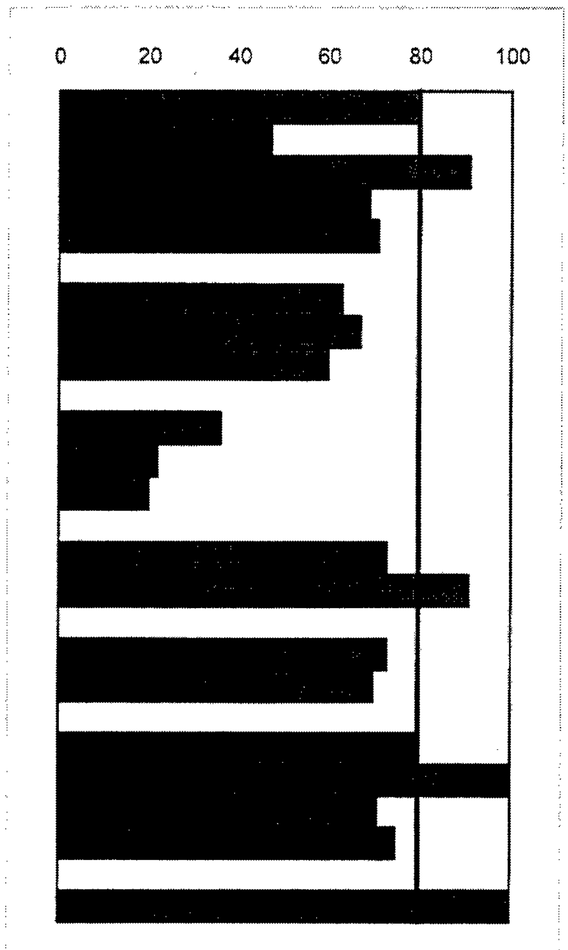


Figure 3-1 Single Aircraft Task Composite Ratings

MULTIPLE AIRCRAFT

% of Tasks Ratings 3 or Higher		Composite
Basic Tasks	*	80
Close Formation/Formation Rejoi		47
Weapon System Checks		91
Ranging Exercises		69
Air-to- Air Exercises		71
Tactical Formation		63
Medium Altitude (10-20K Feet)		67
Low Altitude (300-5K Feet AGL)		60
Threat Reaction		36
Air-to-Air		22
Surface-to-Air		20
Visual Weapons Delivery	**	73
Target ID (IP/Target/Reattack)		91
Types		
Low Altitude	**	73
High Altitude		70
Air-to-Air Tasks	*	80
Intercepts		100
Basic Fighter Maneuvering		71
Air Combat Maneuvering		75
General Situation Awareness		100



*** Tasks Not Meeting Second Criterion (Downgraded to Not Acceptable)**

**** Tasks Meeting Second Criterion (Upgraded to Acceptable)**

Figure 3-2 Multiple Aircraft Task Composite Ratings

NOTE: Drawing not to scale

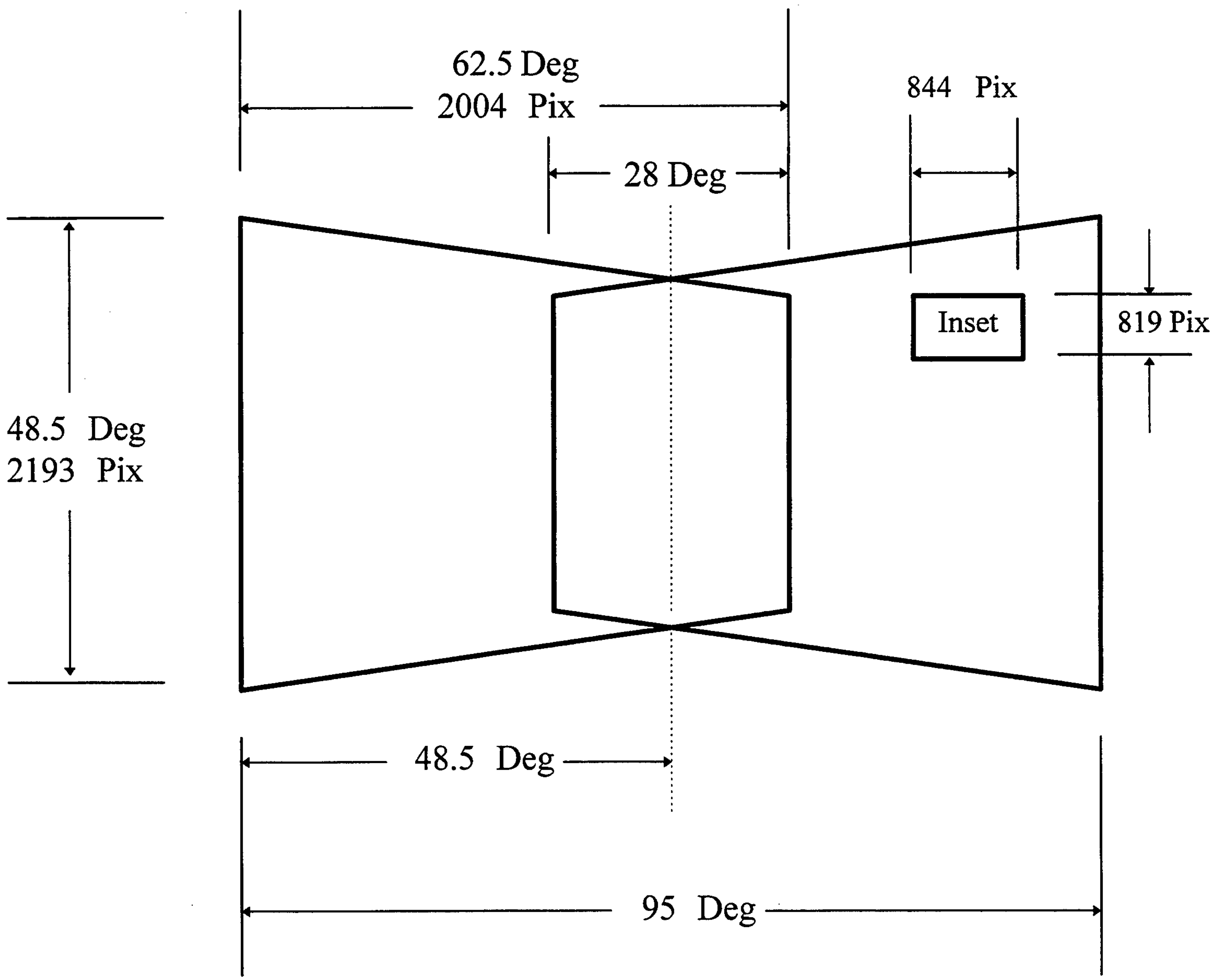


Figure 3-3 MFS FOV Description

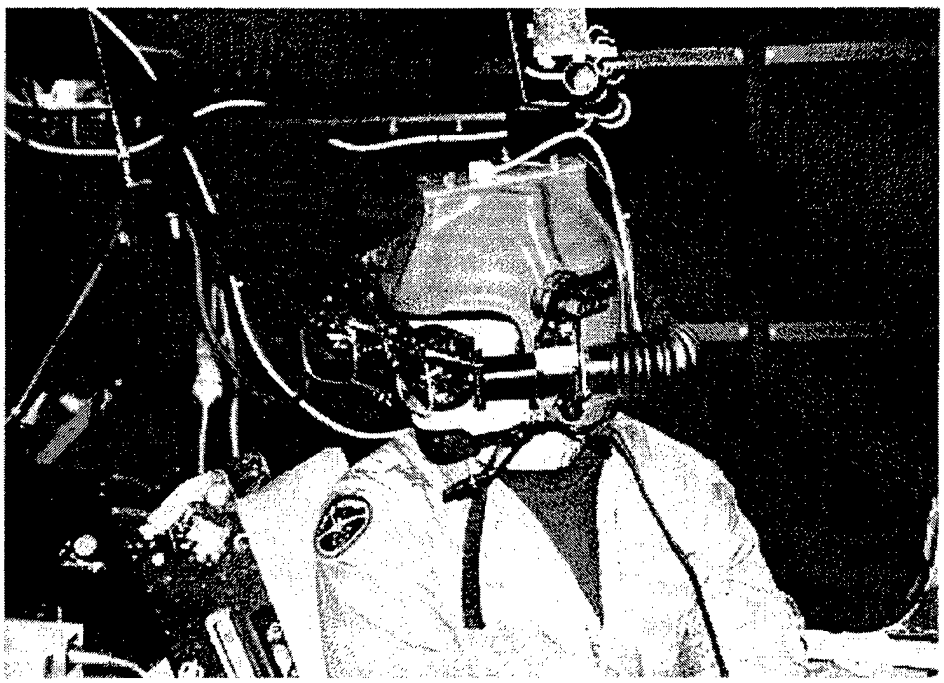


Figure 3-4 AFOHMD System

3.1.2 Engineering Performance

The second objective of this evaluation was to baseline and document the engineering attributes of the Advanced FOHMD.

3.1.2.1 Visual Display. The display has a normal instantaneous field-of-view of 48 degrees vertical by 95 degrees horizontal. The HMD can be used to look anywhere within the pilot's head movement envelope. The full field-of-regard is essentially restricted only by aircraft structure. The display system consisted of two ultra high resolution CRT projectors, two fiber optic bundles to relay the imagery to the helmet optics, pancake window optics to collimate the imagery at 20 feet (or more) and an occulometer to track the pilot's eye for positioning the high resolution inset. Each eye is fed a separate combined inset and background channel. A standard HUD is used which is viewed through the display optics. Detailed performance characteristics of the display system are provided in Annex H of this report.

3.1.2.2 Visual Image Generator. The out-the-window imagery is generated by a four channel CAE Electronics MAXVUE ™ IG. The IG creates separate imagery for each eye including a background and inset (left eye background, left eye inset, right eye background and right eye inset). The background and inset channels for each eye are combined in a post processor on a single raster which is then fed to the CRT projectors. Details of the MAXVUE ™ IG performance is provided in Annex H of this report.

3.1.2.3 Visual Data Base. The database used in this evaluation was a subset of the AV-8B West Coast Database (4X7 degrees, N32-36 degrees, W112-119 degrees). This database was rehosted from a CompuScene IV/A to the MAXVUE ™ IG. Details of the database performance are provided in Annex H of this report.

3.1.2.4 Mini Crew Station Console. The Mini Crew Station consisted of a console with a CRT displaying simulated aircraft instruments, two throttles, a side stick controller, a keyboard and a three monitor display above the instrument CRT providing an out the window visual display. Initially, for the first two pilot teams, an ESIG 2000 IG provided a data base for horizon reference only that was not correlated in location or altitude with that seen in the evaluation cockpit. On Saturday of the first week, the IG was changed to a CompuScene IV/A with a data base fully correlated with that seen in the evaluation cockpit. This was the only system change made during the evaluation. Above the console was an additional monitor displaying the evaluation cockpit HUD display. On a blackboard sized display was a dynamic plan view of the selected low level route and all aircraft involved. Accurate range to the other aircraft was available only from a separate visual system control console. The Mini Crew Station console controlled an FA-18A flight simulation but was designed to be used to control a flyable target, not to control another aircraft in a formation or to provide training. For this evaluation, one of team pilots used this console to provide the other aircraft for all multiple aircraft tasks including tactical and close formation (both lead and wing) as well as Basic Fighter Maneuvering (BFM) and Air Combat Maneuvering (ACM).

3.2 GENERAL TECHNICAL OBSERVATIONS

3.2.1 Changes Implemented On Patuxent River FOHMD System

CAE has implemented significant changes to the AFOHMD System at Patuxent River compared to the FOHMD system evaluated in Vis-Eval I at Stolberg, Germany (1994). The most significant changes are as follows:

3.2.1.1 Projectors. CAE originally used four GE Talaria light valve projectors. Two were for the background channels and two for the inset. The inset was a separate raster concentrating the entire raster into the inset area (i.e., 1000 lines). The new approach uses only two projectors (one for each eye). Instead of light valve projectors, high resolution (2000 line) CRT projectors are used. The inset scheme is entirely different. A single raster is used for both background and inset. The difference between the background and the inset is in the way pixels of information are computed by the image generator. CAE uses what they refer to as Spans in the background. A span is 3 pixels by 3 pixels which receives a single pixel of IG information. This reduces the IG pixels required in the background by a factor of 9 to 1 which greatly reduces the load on the IG. The inset is written pixel for pixel giving it a resolution three times higher than the background. Advantages and disadvantages of the new projection scheme are as follows:

3.2.1.1.1 Projector Advantages:

(1) The CRT projectors have higher contrast than the light valve projectors. The measured contrast ratio was 22.8 to 1 (left eye) and 27.5 to 1 (right eye) versus 9 to 1 at Stolberg.

(2) The use of a single raster (projector) for each eye has advantages over separate rasters (projectors) for the background and inset. With a single raster, the inset is almost transparent to the viewer. Pilots expressed that they did not notice the inset unless they specifically looked for it. The transparency of the inset may be attributed to several factors. Since there is only a single raster, there is no difference in color, brightness, and sharpness between the inset and the background as is the case with a separate inset raster. Also, there is no transition/blend zone between inset and background. On earlier systems, the transition zone together with differences in performance were distracting factors. The only difference between the inset and background of the AFOHMD is the increased detail provided in the inset. Tracking this detail to the viewer's eye essentially makes the display perform similar to the behavior of the viewer's eye.

(3) There is an obvious growth path with this display system. The projectors used on the AFOHMD are capable of providing high resolution detail throughout the field of view including the background. The only reason for the inset is to reduce the number of pixels required to be output by the IG. IG cost is driven principally by pixel processing power requirements. The projectors are each capable of displaying 4.4 megapixels for a total of 8.8 megapixels. It would be very expensive to provide an IG capable of processing this number of pixels. By using the inset and a background with spanning, each inset (which displays pixel for pixel with the IG) requires only 0.7 megapixels and each background requires only one pixel update from the IG for each nine displayed, or 0.4 megapixels. This results in a total of 1.1 megapixels for each eye

and 2.2 megapixels for both eyes. Therefore, this approach requires only 25 percent of the IG pixel processing power that would be required if the entire display were updated by the IG pixel for pixel. As more powerful IG's become available at a lower cost, it is conceivable that the inset could be eliminated, together with the eye tracker, and the IG could update the display pixel for pixel.

(4) Lower life cycle cost due to two CRT projectors versus four expensive light valve projectors.

3.2.1.1.2 Projector Disadvantages:

(1) A smaller background field-of-view (48 X 95 degrees versus 66 X 127 degrees at Stolberg). One reason to minimize the background FOV in this system is that the larger the FOV of the background, the lower the resolution of the inset. With earlier devices, the background FOV did not affect inset resolution.

(2) Less potential resolution in the inset. The new inset has only 37 % of the projector's raster both horizontally and vertically.

(3) A post processor is necessary to combine the high resolution inset channel into the low resolution background channel of the IG. This is done within the MAXVUE ™. Therefore, a MAXVUE ™ must be used as the IG in order to take advantage of the high resolution inset.

3.2.1.2 Eye Tracking. The eye tracking system appears to be much improved over what was experienced at Stolberg and generally what has been experienced on other display systems. Very little effort was needed in the way of calibration. It tracked well with all pilots including those wearing glasses. Only one of the twelve (8 evaluation and 4 other) pilots who flew the system had any difficulty with eye tracking. This individual did not consider it serious. A serious problem occurred when the pilot looked well aft of the 3-9 o'clock quadrants where the fiber optic bundle turned the helmet on the pilot's head causing loss of tracking.

3.2.1.3 Pilot's Eye Relief. A problem with the Stolberg FOHMDs has been that the optics were so close to the pilot's eyes that it was difficult to look down into the cockpit to view the controls and instruments. The optics included on the system at Patuxent River have been moved out so that the pilot can look under the optics to view the controls and instruments.

3.2.2 Positive Pilot Findings

3.2.2.1 Background Resolution. The pilots all reported that the high resolution inset was not noticeable unless they looked for it. The inset area was essentially indiscernible to the pilot from the background. Also, they were not aware of the fall off of resolution outside the inset which was a problem the pilots reported at Stolberg. This may be either because of higher resolution and contrast of the background imagery, the inset is not highlighted by a halo effect, or both. Having background and inset on different rasters may be a major reason for the visibility of the inset at Stolberg.

3.2.2.2 Low Altitude Cueing. All pilots agreed that judging altitude at low level was very effective, especially with the trees on a desert background. This may be largely due to the effectiveness of the database (i.e., high contrast) and the multiple layers of texture.

3.2.2.3 Field-of-Regard. Pilots all felt that the 360 degree field-of-regard made tactical maneuvering very effective. However, they did not like the problems associated with the helmet slipping due to the fiber optic cable bundle when trying to look back beyond 3 or 9 o'clock.

3.2.3 Negative Pilot Findings

3.2.3.1 Imagery Swimming. The head tracker is not magnetically mapped to the cockpit. This resulted in image perturbation when the pilot moves his head within the cockpit.

3.2.3.2 Fiber-Optic Bundle. When the pilot turns his head into the 3-9 o'clock quadrants, the rate sensor may catch the bundle which is in the path of the rate sensor. When this happens, the pilot's head becomes trapped, requiring outside assistance to free his head. Broken fibers appeared as black dots which were distracting during the search for air-to-air targets.

3.2.3.3 Fiber-Optic Bundle Support Structure. The support structure is very close to the helmet resulting in image jump or jitter when the rate sensor contacts the support structure.

3.2.3.4 Helmet

3.2.3.4.1 Helmet Weight. All pilots complained about helmet weight. The helmet contains the pancake window optics, occulometer, head tracker sensor and rate sensor in addition to the liner. There may also be some weight load from the fiber optics bundle; however, it is counter balanced to relieve that load. Significant weight reduction should be accomplished. For example, the optics mounting brackets are relatively massive and the helmet is relatively thick and heavy.

3.2.3.4.2 Helmet Liner. Pilots found the process used to pour or foam the helmet liner to be very uncomfortable and time consuming. The process involved to pour the helmet liner required approximately 45 minutes. An additional hour or more was required to trim and finish the liner.

3.2.3.4.3 Helmet Comfort. Some pilots found the poured helmet very uncomfortable, especially after 45 minutes to an hour in the cockpit when hot spots started to be noticed. The fact that the chin strap had to be very tight to prevent the helmet from slipping added to this discomfort. The chin strap is not an acceptable means of stabilizing the helmet.

3.2.3.5 Optics Exit Pupil. The exit pupil of the optics is relatively small, approximately 15 mm. When pilots made extremely large and/or fast head movements, they found they would lose the image for one or both eyes. This was especially true when looking into the 3-9 o'clock quadrants. If the helmet was not properly fitted and/or the chin strap was not extremely tight, the probability of the eyes moving out of the exit pupil was much greater. If the optics were not precisely aligned to the center of the pilot's eyes, the probability of the eyes moving out of the exit pupil was much greater. The Manned Flight Simulator Facility is currently looking at a double inflatable football helmet liner which could be more comfortable and provide a better fit to reduce slippage of the helmet.

3.2.3.6 Limited Background FOV. The AFOHMD at Patuxent River has an instantaneous FOV for both eyes of approximately 48 degrees vertical by 95 degrees horizontal which is somewhat smaller than the FOHMD at Stolberg. Moving the optics out in order to provide greater eye relief without increasing their diameter may account for the smaller FOV. Even though the FOV of this device is less than earlier devices, pilots had little objection to the limited FOV. This may be due to the overall better performance of this device compared to the earlier devices. Generally, the pilots compensated for the limitation of the FOV by increased head movements and did not feel that it was a serious deficiency in the system. Since the projection system in this AFOHMD exhibits the very best state-of-the-art performance, it is not practical to increase the FOV unless resolution is compromised.

3.2.3.7 Cockpit Lighting. Several pilots expressed concern that the low light level within the cockpit would be distracting to a student who is trying to learn the cockpit layout. The cockpit lighting level is kept low in order to minimize ghosting within the display.

3.2.4 NonVisual Display Pilot Observations

3.2.4.1 Database. Pilots generally liked the database used during the evaluation. They especially liked the green trees on brown terrain which they said provided very good low altitude cues. They felt that the green trees on the green terrain lacked contrast and did not provide good low altitude cues. The pilots said that flight over water was difficult because of the lack of altitude cues, and on two occasions, suggested that white caps might be added as an altitude cue.

3.2.4.2 Mini Crew Station. A separate station with limited controls, a keyboard, and three display monitors was used as a second aircraft during the evaluation. This station did not replicate a cockpit. MFS refers to this as the Mini Crew Station. This station was configured as an FA-18A. Originally, the pilots complained that this station did not provide a matching database. Neither the displayed terrain nor the altitude was correlated with the simulated cockpit. On Saturday of the first week, a CompuScene IV/A IG was connected to the mini crew station in place of the ESIG 2000 to provide a database which matched the MAXVUE ™. In addition, x-y position and altitude was correlated between the stations. As a result, the pilots exhibited a much better performance in flying the Mini Crew Station for the multiple aircraft missions.

3.2.4.5 Landing ground reactions. Several of the pilots expressed concern that when attempting to take off or land, there did not appear to be any ground reaction simulation. Brakes and nose wheel steering seemed to have little effect.

3.2.4.6 Own Ship Masking. The IG does not currently model the twin tail section of the FA-18 and provides only a blocked out area in the rear quarter. On one occasion, a pilot stated that the mask for the wings was not properly sized. The pilot's view of the exterior of the aircraft must reflect proper occulting of the out-the-cockpit scene by exterior aircraft structure (i.e. wings, tail section, etc.). Such changes are computed in the IG.

3.2.4.7 Image Overload. There were several complaints that the image would appear to jump across the screen in steps. The cause of this was the IG dropping the update rate from 60 hertz to 30 hertz to avoid overloading during rapid image movements caused by a combination of rapid pilot head movements and rapid aircraft movements. These rapid head movements occurred during normal ACM and defensive BFM.

3.2.4.8 HUD Field-of-View. Several of the pilots expressed that it was necessary to move their head to view all of the information within the HUD. The HUD optics for the simulator were from an FA-18A while the symbology displayed was for an F/A-18C. This caused the observed mis match.

3.2.5 Other Findings

3.2.5.1 Availability. There were no system failures within the Visual System or other Simulator Systems which caused the device not to be available during the eight working days when the evaluation was conducted.

3.2.5.2 Fiber-Optic Bundle Wear. MFS personnel at Patuxent River checked the fiber optics in the fall of last year and again this spring to find there was no noticeable change in fiber breakage in the bundles over a six month time period. Although the AFOHMD usage would not be as high as that for a training system, this reduced breakage is an encouraging trend.

3.2.5.3 Cockpit Systems. During the evaluation of the visual display technology, the importance of the cockpit and the integration of the cockpit systems to the visual system was identified as a factor in the evaluation. Despite the initial unfamiliarity of some pilots with the FA-18 cockpit systems, those pilots quickly adapted resulting in no negative impact to the evaluation process.

3.2.5.4 Database. Throughout the visual evaluations, the importance of the scene content and scene detail of the visual presentations continued to surface. Areas with low scene content did not provide sufficient speed cues. Areas with high contrast green trees on desert provided much improved speed cues.

3.2.5.5 Texturing. The evaluation team believed that texturing in the displayed image can provide helpful cues for low altitude flight. Texturing should become sharper in focus as the range from the textured object decreases. Multiple levels of texturing are a possible solution and should be evaluated. High contrast generic objects such as green trees against a brown terrain are much more effective than low contrast generic objects such as green trees on a green terrain. The pilots felt that texture white caps over water could also be useful as an altitude cue.

3.2.5.6 Physiological Effects. Each pilot was asked at the conclusion of each debrief whether they experienced any form of illness such as nausea or disorientation. No significant instances were reported. Several pilots responded that they experienced some eye strain. This may have been due to pilots squinting while trying to see objects or determine aspect.

SECTION 4 - CONCLUSIONS

Paragraph references shown below contain supporting data relating to each conclusion.

4.1.1 The AFOHMD was evaluated as being capable of supporting USAF Formal Training Unit (FTU) and USN/USMC Fleet Replacement Squadron (FRS) training for 82% (9 of 11) of the single aircraft tasks and 25% (5 of 20) multiple aircraft tasks evaluated based upon the composite ratings. (para 3.1.1.2 and Figures 3-1 and 3-2)

4.1.2 As discussed in paragraph 3.1.1.2, multiple aircraft acceptable ratings improved markedly between the first week of the evaluation (Teams 1&2) and the second week (Teams 3&4) after a change was made to the Mini Crew Station Console to permit better control of the second aircraft. Multiple aircraft acceptable task ratings improved from 20% to 80% (para 3.1.1.2 and Annex G). We have concluded that the evaluation of the visual display subsystem can be significantly impacted by improvements to supporting subsystems, such as the Mini Crew Station Console, that allow pilots to perform tasks more easily and more accurately. Unless the same pilots are able to evaluate the simulator both before and after the change, it is difficult to isolate the true effect of the change ; the effect may only be inferred. (Annex G)

4.1.3 The AFOHMD helmet has significant human factors limitations including helmet and display weight, fiber optic bundle restrictions on head movement, interference between fiber optic bundles/sensors and system hardware, helmet slippage and helmet comfort. Significant efforts are required to address these issues to improve system performance during BFM and ACM. (paras 3.1.1.2.3.5.2 and 3.1.1.2.3.5.3)

4.1.4 The AFOHMD required a special helmet liner and calibration procedure for use. (para 3.2.3.4)

4.1.5 Appropriate aircraft masking must be provided to properly occult the out-of-the-cockpit scene. (para 3.2.4.6)

4.1.6 Visual threat simulations must be significantly improved to provide acceptable training. (paras 3.1.1.2.2.1.3 and para 3.1.1.2.3.3).

4.1.7 There were no significant instances of physiological effects such as nausea or disorientation reported during the evaluation. (para 3.2.5.6)

SECTION 5 - RECOMMENDATIONS.

5.1 Prior to any commitment to procure this or a similar type of display device, the human factors issues identified in this report that limit pilot performance must be addressed.

5.2 The evaluation process used in the Joint Vis-Eval should be continued to test visual system capabilities against USAF Formal Training Unit (FTU) and USN/USMC Fleet Replacement Squadron (FRS) training tasks. This process will enable the user and the acquisition community to develop more realistic expectations of training systems capability.

5.3 Manufacturers of visual systems need to thoroughly understand the users training requirements to optimize the training capability of the system.

5.4 The training system must be viewed as a matched set of visual and other simulator subsystems designed to meet realistic training requirements. Training capability of the system may be severely limited by any weak subsystem.

5.5 Future evaluations should be preceded by distribution of the planned mission task outline to both the facility operator and visual system manufacturer. Following review of this document, discussions should be held between the evaluation team and these organizations to insure that the operator and manufacturer understand how the evaluation will be conducted and to allow them time to optimize the system to reflect the best potential operation for the evaluation.

5.7 Care must be taken that simulation system limitations do not cause the visual system ratings to be skewed by nonvisual performance. This may have been the case during this evaluation where the database displayed to Teams 1 & 2 at the mini crew station console was not correlated in position or altitude with that at the evaluation cockpit (para 2.3.1.5; paras 3.1.1.2 and 3.1.1.2.1). When changes are made during the evaluation, the simulation system must be evaluated by the same teams both before and after the change to determine the true impact of the change.

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ANNEX A

STATEMENT OF JOINT VISUAL EVALUATION OBJECTIVE

o Determine trainability of Air-to-Air and Air-to-Surface tasks on available visual display technology

- Trainability is defined as the visual system's ability to present a simulated visual environment which allows development of skills transferable to the aircraft and minimizes development of simulator unique skills

- Level of training of USAF Formal Training Units (FTU) and USN/USMC Fleet Replacement Squadrons (FRS)

o Demonstrate current visual simulation technology to users

o Get feedback from those users to help define future visual system requirements

o Provide information and data to support future decisions

ANNEX B

EVALUATION TASK OUTLINE

A familiarization mission and two generic tactical evaluation missions were developed to permit each pilot to evaluate each of 19 single aircraft and 54 multi-aircraft tasks and subtasks. Not all tasks and subtasks were flown on each mission, but the missions were structured to cover each task and subtask at least once during the evaluation. The Familiarization Mission was structured to orient pilots to the F/A-18 and the visual system as well as overcome "first impressions". Each evaluation mission consisted of a set of suggested events (Air to Surface, Air to Air, formation, threat reaction, etc.) to evaluate the tasks and subtasks in a mission context. Mission events increased in complexity from single aircraft tasks and subtasks in the beginning of Mission 1 to complex multi aircraft tasks and subtasks later in Mission 1 and in Mission 2. The tasks, sub tasks, missions and mission events were developed by the Joint Vis Eval Pilot Team during an initial meeting six weeks prior to the evaluation and approved by the Evaluation Team Chief. For purposes of this evaluation, the underlined exercises were evaluated as tasks; the remainder were considered subtasks.

1. SINGLE AIRCRAFT TASKS

- 1.1 <u>Low Level (300 - 5k foot AGL)</u>
  - 1.1.1 <u>Navigation</u>
  - 1.1.2 <u>Low Altitude Training (LAT)</u>
  - 1.1.3 <u>Detect/Identify Ground Threat</u>

- 1.2 <u>Medium Altitude Maneuvering (10k - 20k foot altitude)</u>

- 1.3 <u>Visual Weapons Delivery</u>
  - 1.3.1 <u>Low Altitude</u>
    - 1.3.1.1 Low Angle Strafe (LAS)
    - 1.3.1.2 Low Angle Low Drag (LALD)
    - 1.3.1.3 Low Angle Bomb (LAB)
    - 1.3.1.4 Visual Lay Down (VLD)
  - 1.3.2 <u>High Altitude</u>
    - 1.3.2.1 High Angle Strafe (HAS)
    - 1.3.2.2 High Angle Dive Bomb (HD)
    - 1.3.2.3 Dive Bomb (DB)

- 1.4 <u>Approach/Landing</u>
  - 1.4.1 <u>Day</u>
  - 1.4.2 <u>Night</u>

- 1.5 <u>General Situation Awareness (SA)</u>

2. MULTIPLE AIRCRAFT TASKS

- 2.1 Basic Tasks
  - 2.1.1 Close Formation/Formation Rejoin
  - 2.1.2 Weapon System Checks
  - 2.1.3 Ranging Exercises
    - 2.1.3.1 Offensive
    - 2.1.3.2 Defensive
  - 2.1.4 Air-to-Air Exercises
    - 2.1.4.1 Snap Shot
    - 2.1.4.2 Heat to Guns

- 2.2 Tactical Formation
  - 2.2.1 Medium Altitude (10k - 20k foot altitude)
    - 2.2.1.1 Line Abreast/Combat Spread (3k - 12k foot range)
      - Range specified by Flight Lead
    - 2.2.1.2 Wedge/Tactical Wing (3k - 12k foot range)
      - Range specified by Flight Lead
    - 2.2.1.3 Deploy/Rejoin
  - 2.2.2 Low Altitude (300 - 5k foot AGL)
    - 2.2.2.1 Line Abreast/Combat Spread (3k - 12k foot range)
      - Range specified by Flight Lead
    - 2.2.2.2 Wedge/Tactical Wing (3k - 12k foot range)
      - Range specified by Flight Lead
    - 2.2.2.3 Deploy/Rejoin

- 2.3 Threat Reaction
  - 2.3.1 Air-to-Air
  - 2.3.2 Surface-to-Air

- 2.4 Visual Weapon Delivery
  - 2.4.1 Target Identification (IP/Target/Reattack)
  - 2.4.2 Types
    - 2.4.2.1 Low Altitude
      - 2.4.2.1.1 Echelon Attack
        - 2.4.2.1.1.1 Low Angle Strafe (LAS)
        - 2.4.2.1.1.2 Low Angle Low Drag (LALD)
        - 2.4.2.1.1.3 Low Angle Bomb (LAB)
        - 2.4.2.1.1.4 Visual Lay Down (VLD)
      - 2.4.2.1.2 Split Attack
        - 2.4.2.1.2.1 Low Angle Strafe (LAS)
        - 2.4.2.1.2.2 Low Angle Low Drag (LALD)
        - 2.4.2.1.2.3 Low Angle Bomb (LAB)
        - 2.4.2.1.2.4 Visual Lay Down (VLD)

- 2.4.2.2 High Altitude
  - 2.4.2.2.1 Echelon Attack
    - 2.4.2.2.1.1 High Angle Strafe (HAS)
    - 2.4.2.2.1.2 High Angle Dive Bomb (HD)
    - 2.4.2.2.1.3 Dive Bomb (DB)
  - 2.4.2.2.2 Split Attack
    - 2.4.2.2.2.1 High Angle Strafe (HAS)
    - 2.4.2.2.2.2 High Angle Dive Bomb (HD)
    - 2.4.2.2.2.3 Dive Bomb (DB)

2.5 Air-to-Air Tasks

- 2.5.1 Intercepts
  - 2.5.1.1 Medium Altitude (10k - 20k foot altitude)
  - 2.5.1.2 Low Altitude (300 - 5k foot AGL)
  - 2.5.1.3 Tally Ho/Visual Identification
- 2.5.2 Basic Fighter Maneuvering (BFM)
  - 2.5.2.1 9k, 6k, 3k foot range and High Aspect Angle
  - 2.5.2.2 Maneuvering
  - 2.5.2.3 Weapons Employment
- 2.5.3 Air Combat Maneuvering (ACM)
  - 2.5.3.1 3 - 3.5 Nautical Mile Setups
  - 2.5.3.2 Weapons Employment

2.6 General Situation Awareness (SA)

ANNEX C

JOINT VISUAL EVALUATION SORTIE EVENTS

0. Familiarization Sortie

0.1 Takeoff (Single Aircraft)

0.2 Low Altitude Training (LAT)
- 0.2.1 Navigation
- 0.2.2 Low Altitude Maneuvering
- 0.2.3 Terrain Masking

0.3 Air-to-Surface Weapons Delivery Familiarization
- 0.3.1 Air-to-Surface Switchology
- 0.3.2 Low Angle - 10 Degree Pop Up
- 0.3.3 Low Angle Strafe
- 0.3.4 Visual Lay Down
- 0.3.5 Medium Angle - 20 Degree Pop Up
- 0.3.6 High Angle - 30 Degree Pop Up

0.4 Medium Altitude Maneuvering
- 0.4.1 Aircraft Handling Characteristics (AHC)
- 0.4.2 Air-to-Air Switchology

0.5 Intercepts
- 0.5.1 Medium Altitude
- 0.5.2 Low Altitude

0.6 Exercises
- 0.6.1 Offensive/Defensive Ranging Exercises
- 0.6.2 Heat to Gun Conversions

0.7 Offensive BFM (3 Engagements)
- 0.7.1 9k foot Perch
- 0.7.2 6k foot Perch
- 0.7.3 3k foot Perch

0.8 Straight in approach for touch and go landing (at IFR minimums)

0.9 Overhead traffic pattern to landing (at VFR overhead minimums)

1. Mission 1

- 1.1 Takeoff/Rejoin

- 1.2 Low Altitude Tactical Formation
  - 1.2.1 Low Altitude Training (LAT)
  - 1.2.2 Navigation
  - 1.2.3 Terrain Masking
  - 1.2.4 Threat Reaction
    - 1.2.4.1 Air-to-Air
    - 1.2.4.2 Surface-to-Air

- 1.3 Initial Point (IP) to Target Run

- 1.4 Air-to-Surface Attacks / Reattacks
  - 1.4.1 Low Angle - 10 Degree Pop Up
  - 1.4.2 Low Angle Strafe
  - 1.4.3 Visual Lay Down
  - 1.4.4 Medium Angle - 20 Degree Pop Up
  - 1.4.5 High Angle - 30 Degree Pop Up

- 1.5 Medium Altitude Tactical Formation(10k - 20k foot altitude)
  - 1.5.1 Line Abreast/Combat Spread (3k - 12k foot range)
    - Range specified by Flight Lead
  - 1.5.2 Wedge/Tactical Wing (3k - 12k foot range)
    - Range specified by Flight Lead
  - 1.5.3 Deploy/Rejoin

- 1.6 Intercepts (1 v 1)
  - 1.6.1 Medium Altitude - High to Low
  - 1.6.2 Low Altitude - Low to High
  - 1.6.3 Low Altitude - Level

- 1.7 Basic Fighter Maneuvering (BFM)
  - 1.7.1 9k foot Perch
  - 1.7.2 6k foot Perch
  - 1.7.3 3k foot Perch
  - 1.7.4 High Aspect Butterfly

- 1.8 Exercises
  - 1.8.1 Offensive/Defensive Ranging Exercises
  - 1.8.2 Heat to Gun Conversions

- 1.9 Snap Shot Exercise on RTB

1.10 Straight in approach for touch and go landing (at IFR minimums)
    1.10.1 Day
    1.10.2 Night

1.11 Overhead traffic pattern to landing (at VFR overhead minimums)
    1.11.1 Day Only

2. Mission 2

2.1 Takeoff/Rejoin

2.2 Low Altitude Tactical Formation
    2.2.1 Low Altitude Training (LAT)
    2.2.2 Navigation
    2.2.3 Terrain Masking
    2.2.4 Threat Reaction
        2.2.4.1 Air-to-Air
        2.2.4.2 Surface-to-Air

2.3 Initial Point to Target Run

2.4 Attacks / Reattack
    2.4.1 Low Altitude Split / Echelon Pop Up
    2.4.2 Medium Altitude Fly up / Level Roll-in

2.5 Intercepts to ACM Engagement
    2.5.1 Low Altitude vs Medium Altitude Bandit
        - Stern conversion to ACM
    2.5.2 Medium Altitude vs Medium Altitude Bandit
        - Stern conversion to ACM
    2.5.3 Medium Altitude vs Low Altitude Bandit
        - Beam Conversion to ACM
    2.5.4 Medium Altitude vs Medium Altitude Bandit
        - Radar missile defense

2.6 Straight in approach for touch and go landing (at IFR minimums)
    2.6.1 Day
    2.6.2 Night

2.7 Overhead traffic pattern to landing (at VFR overhead minimums)
    2.7.1 Day Only

ANNEX D

BACKGROUND OF EVALUATION PILOTS

Eight pilots were selected for this evaluation including four Air Force, two Navy, and two Marine pilots. All pilots had extensive fighter and fighter instructor pilot experience in the F-15, F-16 or F/A-18 with one of the pilots having combat experience. Both Marine pilots were Top Gun graduates. The average flying time for the pilots was 2275 hours; average instructor time was 788 hours. Each pilot completed the following background questionnaire:

PILOT BACKGROUND QUESTIONNAIRE

NAME AND GRADE____
DATE________________

ORGANIZATION
____________________________________LOCATION____________________

PILOT NUMBER________________________TELEPHONE:
COMMERCIAL____________________
DSN____________________

FAX____________________

TYPE OF AIRCRAFT PRESENTLY FLYING : (Check one and indicate hours flown)

F-15C___ F-15E___ F-16C___Block#___ F/A-18___ F-14___

Hours_____
IP Hours_____

COMBAT EXPERIENCE:

Aircraft Type:_________ Combat Hours______ Combat Missions______

CURRENT DUTY: (e.g., instructor pilot, staff officer, etc.)

____

OTHER INSTRUCTOR AND FIGHTER AIRCRAFT FLYING EXPERIENCE:
(list aircraft and approximate flying hours)

____
____
____
____
____
____

TOTAL FLYING TIME_______________ **TOTAL IP TIME**_______________

ANNEX E

JOINT VISUAL EVALUATION RATING SCALE

0.....Provides negative training. Training detracts from performance in aircraft or encourages hazardous techniques. Has major deficiencies.

1.....No similarity between visual simulation and aircraft training. Cannot train requirement with visual system. Has major deficiencies.

2.....Little similarity between visual simulator and aircraft training. Only minimal training can be accomplished using visual system.

3.....Training capability is acceptable. Essential parts of the task can be taught with this visual system.

4.....Visual training capability is nearly equal to that experienced in the aircraft. Most of the task can be trained with this visual system.

5.....Training capability equal to that experienced in the aircraft. Task can be fully trained with visual system.

Comment Considerations

Comment on any of the following conditions if they contributed to a rating of less than 3 for any task or sub-task.

A. Did you have to perform any task differently in the simulator than you would in the aircraft?

B. Were there any required cues that were different or missing in the simulator?

C. Were you able to determine range, rate of closure and aspect angle with sufficient accuracy to perform the task?

D. Did the aircraft, aircraft system and avionics simulation support performance of the task?

E. Were there any visual display characteristics (i.e. resolution (object detail), brightness, contrast, distortion, field of view, field of regard, area of interest, spurious images, blemishes, transport delay, placement of hardware or other characteristics) that impacted your performance of the task?

F. Were there any data base characteristics that detracted from or enhanced your ability to perform the task?

G. Were the HUD and aircraft systems accurately correlated with the visual system?

H. Were you able to appropriately use in-cockpit references if they were required?

I. What visual system improvements would you consider most important to improve your task ratings?

J. Other?

ANNEX F

SAMPLE DATA COLLECTION FORMS

JOINT VISUAL EVALUATION AIRCREW QUESTIONNAIRE

Name ____________________
Mission FAM____ 1____ 2____
Date ____________________
Debriefer ____________________

TASK RATING SCALE:

- 0 Provides Negative Training
- 1 No similarity, cannot train
- 2 Little similarity, minimal training
- 3 Acceptable training capability, teach essential parts of task
- 4 Nearly equal to aircraft, train most of task
- 5 Nearly equal to aircraft, fully train task

Note: If you rate any task or sub-task less than 3, please circle the condition that applies and explain in comments. If more space is required, use back of page. If a task or sub-task is not performed, enter N/A in rating block.

Section 1 - Single Aircraft Tasks

1.1 Low Level — Task Rating ___

- 1.1.1 Navigation — Sub-task Rating ___
- 1.1.2 Low Altitude Training (LAT) — Sub-task Rating ___
- 1.1.3 Detect / Identify Ground Threat — Sub-task Rating ___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

1.2 Medium Altitude Maneuvering   Task Rating ___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, Circle the condition(s) that apply and explain.

- A. Task different in simulator than in aircraft?
- B. Required cues different or missing?
- C. Range, closure rate, aspect angle accuracy ?
- D. Aircraft simulation support the task?
- E. Display characteristics impact task?
- F. Data base detract from or enhance task?
- G. HUD, aircraft, visual accurately correlated?
- H. Appropriately use in-cockpit references?
- I. Priority improvements to improve ratings?
- J. Other

COMMENTS:____

1.3 Visual Weapons Delivery   Task Rating ___

1.3.1 Low Altitude	Sub-task Rating___
1.3.1.1 Low Angle Strafe (LAS)	Sub-task Rating ___
1.3.1.2 Low Angle Low Drag (LALD)	Sub-task Rating ___
1.3.1.3 Low Angle Bomb (LAB)	Sub-task Rating ___
1.3.1.4 Visual Lay Down (VLD)	Sub-task Rating ___
1.3.2 High Altitude	Sub-task Rating___
1.3.2.1 High Angle Strafe (HAS)	Sub-task Rating ___
1.3.2.2 High Angle Dive Bomb (HD)	Sub-task Rating ___
1.3.2.3 Dive Bomb (DB)	Sub-task Rating ___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

- A. Task different in simulator than in aircraft?
- B. Required cues different or missing?
- C. Range, closure rate, aspect angle accuracy ?
- D. Aircraft simulation support the task?
- E. Display characteristics impact task?
- F. Data base detract from or enhance task?
- G. HUD, aircraft, visual accurately correlated?
- H. Appropriately use in-cockpit references?
- I. Priority improvements to improve Ratings?
- J. Other

COMMENTS:____

1.4 Approach/Landing — Task Rating ___

- 1.4.1 Day — Sub-task Rating ___
- 1.4.2 Night — Sub-task Rating ___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

1.5 General Situation Awareness (SA) — Task Rating ___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

Section 2 - Multiple Aircraft Tasks

2.1 Basic Tasks	Task Rating___
2.1.1 Close Formation/Formation Rejoin	Sub-task Rating___
2.1.2 Weapon System Checks	Sub-task Rating___
2.1.3 Ranging Exercises	Sub-task Rating___
2.1.3.1 Offensive	Sub-task Rating___
2.1.3.2 Defensive	Sub-task Rating___
2.1.4 Air-to-Air Exercises	Sub-task Rating___
2.1.4.1 Snap Shot	Sub-task Rating___
2.1.4.2 Heat to Guns	Sub-task Rating___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

2.2 Tactical Formation	Task Rating___
2.2.1 Medium Altitude (10k-20k foot altitude)	Sub-task Rating___
2.2.1.1 Line Abreast/Combat Spread (3k-12k foot range)	Sub-task Rating___
2.2.1.2 Wedge/Tactical Wing (3k-12k foot range)	Sub-task Rating___
2.2.1.3 Deploy/Rejoin	Sub-task Rating___
2.2.2 Low Altitude (300 - 5k foot AGL)	Sub-task Rating___
2.2.2.1 Line Abreast/Combat Spread (3k-12k foot range)	Sub-task Rating___
2.2.2.2 Wedge/Tactical Wing (3k-12k foot range)	Sub-task Rating___
2.2.2.3 Deploy/Rejoin	Sub-task Rating___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

2.3 Threat Reaction — Task Rating___

2.3.1 Air-to-Air — Sub-task Rating___
2.3.2 Surface-to-Air — Sub-task Rating___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

2.4 Visual Weapon Delivery — Task Rating___

2.4.1 Target Identification (IP/Target/Reattack) — Sub-task Rating___
2.4.2 Types
2.4.2.1 Low Altitude — Sub-task Rating___
2.4.2.1.1 Echelon Attack — Sub-task Rating___
2.4.2.1.1.1 Low Angle Strafe (LAS) — Sub-task Rating___
2.4.2.1.1.2 Low Angle Low Drag (LALD) — Sub-task Rating___
2.4.2.1.1.3 Low Angle Bomb (LAB) — Sub-task Rating___
2.4.2.1.1.4 Visual Lay Down (VLD) — Sub-task Rating___
2.4.2.1.2 Split Attack — Sub-task Rating___
2.4.2.1.2.1 Low Angle Strafe (LAS) — Sub-task Rating___
2.4.2.1.2.2 Low Angle Low Drag (LALD) — Sub-task Rating___
2.4.2.1.2.3 Low Angle Bomb (LAB) — Sub-task Rating___
2.4.2.1.2.4 Visual Lay Down (VLD) — Sub-task Rating___
2.4.2.2 High Altitude — Sub-task Rating___
2.4.2.2.1 Echelon Attack — Sub-task Rating___
2.4.2.2.1.1 High Angle Strafe (HAS)
Sub-task Rating___
2.4.2.2.1.2 High Angle Dive Bomb (HD) — Sub-task Rating___

2.4.2.2.1.3 Dive Bomb (DB) Sub-task Rating___
2.4.2.2.2 Split Attack Sub-task Rating___
2.4.2.2.2.1 High Angle Strafe (HAS) Sub-task Rating___
2.4.2.2.2.2 High Angle Dive Bomb (HD) Sub-task Rating___
2.4.2.2.2.3 Dive Bomb (DB) Sub-task Rating___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

2.5 Air-to-Air Tasks Task Rating___

2.5.1 Intercepts Sub-task Rating___
2.5.1.1 Medium Altitude (10k - 20k foot altitude) Sub-task Rating___
2.5.1.2 Low Altitude (300 - 5k foot AGL) Sub-task Rating___
2.5.1.3 Tally Ho/Visual Identification Sub-task Rating___
2.5.2 Basic Fighter Maneuvering (BFM) Sub-task Rating___
2.5.2.1 3k, 6k, 9k foot range and High Aspect Angle Sub-task Rating___
2.5.2.2 Maneuvering Sub-task Rating___
2.5.2.3 Weapons Employment Sub-task Rating___
2.5.3 Air Combat Maneuvering Sub-task Rating___
2.5.3.1 3 - 3.5 Nautical Mile Setups Sub-task Rating___
2.5.3.2 Weapons Employment Sub-task Rating___

If any of the following conditions contributed to a rating of less than 3 for any task or sub-task, circle the condition(s) that apply and explain.

A. Task different in simulator than in aircraft?
B. Required cues different or missing?
C. Range, closure rate, aspect angle accuracy ?
D. Aircraft simulation support the task?
E. Display characteristics impact task?
F. Data base detract from or enhance task?
G. HUD, aircraft, visual accurately correlated?
H. Appropriately use in-cockpit references?
I. Priority improvements to improve ratings?
J. Other

COMMENTS:____

2.6 General Situation Awareness (SA) Task Rating___

COMMENTS:____

Section 3 - General Questions

3.1 What major strengths did you observe in this visual display during this evaluation?

3.2 What major weaknesses did you observe in this visual display during this evaluation?

3.3. During this evaluation sortie, did you experience any physical discomfort such as:

- Simulator sickness (nausea or vomiting)?
- Disorientation?
- Eyestrain?

If so, please describe.

ANNEX G

COMPOSITE RATINGS

	SINGLE AIRCRAFT		Rating
	Percentage of Pilots Rating 3 or Higher		Composite
1.1	**Low Level**	**(T)**	100
1.1.1	Navigation	**(T)**	100
1.1.2	Low Altitude Training	**(T)**	100
1.1.3	Detect/ID Ground Threat	**(T)**	31
1.2	**Medium Altitude Maneuvering**	**(T)**	83
1.3	**Visual Weapons Delivery**	**(T)**	100
1.3.1	Low Altitude	**(T)**	100
1.3.1.1	Low Angle Strafe		88
1.3.1.2	Low Angle Low Drag		100
1.3.1.3	Low Angle Bomb		100
1.3.1.4	Visual Lay Down		71
1.3.2	High Altitude	**(T)**	79
1.3.2.1	High Angle Strafe		75
1.3.2.2	High Angle Dive Bomb		75
1.3.2.3	Dive Bomb		85
1.4	**Approach/Landing**	**(T)**	100
1.4.1	Day	**(T)**	100
1.5	**General Situation Awareness**	**(T)**	100

(T) Differentiates Tasks From Subtasks

Single Aircraft Tasks and Subtasks Composite Ratings

Table G - 1

	MULTIPLE AIRCRAFT		Rating
	Percentage of Pilots Rating 3 or Higher		Composite
2.1	**Basic Tasks**	*** (T)**	80
2.1.1	Close Formation/Formation Rejoin	(T)	47
2.1.2	Weapon System Checks	(T)	91
2.1.3	Ranging Exercises	(T)	69
2.1.3.1	Offensive		75
2.1.3.2	Defensive		17
2.1.4	Air-to- Air Exercises	(T)	71
2.1.4.1	Snap Shot		64
2.1.4.2	Heat to Guns		92
2.2	**Tactical Formation**	**(T)**	63
2.2.1	Medium Altitude (10-20K Feet)	(T)	67
2.2.1.1	Line Abreast/Combat Spread (3-12K Foot Range		60
2.2.1.2	Wedge/Tactical Wing (3-12K Foot Range)		79
2.2.1.3	Deploy/Rejoin		62
2.2.2	Low Altitude (300-5K Feet AGL)	(T)	60
2.2.2.1	Line Abreast/Combat Spread (3-12K Foot Range		60
2.2.2.2	Wedge/Tactical Wing (3-12K Foot Range)		86
2.2.2.3	Deploy/Rejoin		67
2.3	**Threat Reaction**	**(T)**	36
2.3.1	Air-to-Air	(T)	22
2.3.2	Surface-to-Air	(T)	20
2.4	**Visual Weapons Delivery**	**** (T)**	73
2.4.1	Target Identification (IP/Target/Reattack)	(T)	91
2.4.2	Types		
2.4.2.1	Low Altitude	** (T)	73
2.4.2.1.1	Echelon Attack		70
2.4.2.1.1.1	Low Angle Strafe		86
2.4.2.1.1.2	Low Angle Low Drag		80
2.4.2.1.1.3	Low Angle Bomb		73
2.4.2.1.1.4	Visual Lay Down		88

(T) Differentiates Tasks From Subtasks

*** Tasks Not Meeting Second Criterion (Downgraded to Not Acceptable)**

**** Tasks Meeting Second Criterion (Upgraded to Acceptable)**

Multiple Aircraft Tasks and Subtasks Composite Ratings

Table G - 2A

	MULTIPLE AIRCRAFT (Continued)	Rating
	Percentage of Pilots Rating 3 or Higher	Composite
	Visual Weapons Delivery (Continued)	
	Low Altitude **(Continued)**	
2.4.2.1.2	Split Attack	80
2.4.2.1.2.1	Low Angle Strafe	83
2.4.2.1.2.2	Low Angle Low Drag	80
2.4.2.1.2.3	Low Angle Bomb	89
2.4.2.1.2.4	Visual Lay Down	86
2.4.2.2	High Altitude (T)	70
2.4.2.3	Echelon Attack	78
2.4.2.4	High Angle Strafe	75
2.4.2.2.1.2	High Angle Dive Bomb	70
2.4.2.2.1.3	Dive Bomb	75
2.4.2.2.2	Split Attack	83
2.4.2.2.2.1	High Angle Strafe	67
2.4.2.2.2.2	High Angle Dive Bomb	50
2.4.2.2.2.3	Dive Bomb	83
2.5	**Air-to-Air Tasks *(T)**	80
2.5.1	Intercepts (T)	100
2.5.1.1	Medium Altitude (10-20K Feet)	100
2.5.1.2	Low Altitude (300-5K Feet AGL)	100
2.5.1.3	Tally Ho/Visual Identification	43
2.5.2	Basic Fighter Maneuvering (T)	71
2.5.2.1	3K,6K,9K Foot Range and High Aspect Angle	67
2.5.2.2	Maneuvering	77
2.5.2.3	Weapons Employment	42
2.5.3	Air Combat Maneuvering (T)	75
2.5.3.1	3-3.5 Nautical Mile Setups	75
2.5.3.2	Weapons Employment	55
2.6	**General Situation Awareness (T)**	100

(T) Differentiates Tasks From Subtasks

*** Tasks Not Meeting Second Criterion (Downgraded to Not Acceptable)**

Multiple Aircraft Tasks and Subtasks Composite Ratings

Table G - 2B

ANNEX H

DETAILED HARDWARE DESCRIPTION

SITE 1: Advanced Fiber Optic Helmet Mounted Display (AFOHMD) Patuxent River, MD

Detailed Hardware Description. The display performance characteristics show here were either measured on site at Patuxent River or are CAE Spec numbers and are noted as such. Actual measurements are difficult due to the limited exit pupil from which measurements must be made. No measurements were attempted during evaluation.

GENERAL	**Characteristics**
Display name	Advanced Fiber Optic Helmet Mounted Display (FOHMD).
Display type	Head mounted, head and eye slaved, area-of-interest display system.
Location	Manned Fight Simulator, NAWC, Patuxent River, MD.
Display manufacturer	CAE Electronics, Montreal, Canada.
Image generator, manufacturer	Maxvue ™, CAE Electronics, Montreal, Canada.
DISPLAY ATTRIBUTES	
Tracking ability	The magnetic head tracker consists of a Polhemus 3Space Fastrak head tracker with a resolution of 0.08 degrees in rotational axes, and 0.04 inches in all translational axes. Rotational accuracy is 1.0 degrees overall and 0.1 degrees in HUD area. Translational accuracy is 0.1 inches. Additionally, a Watson Industries angular rate sensor is added to minimize latency.
Eye Tracker	The optical eye tracker is an El-Mar Helmet Mounted Monocular System with a range of +/- 40 degrees horizontal and +/- 30 degrees vertical and a resolution of 0.1 degree. Update rate is 120HZ. The eye is illuminated by three infra-red LEDs and read by an infra-red camera. Infra-red intensity is 400 mircowatts per square centimeter. Insensitivity to translation of helmet to head for +/- 5 mm is less than 0.1 degree error.
Field-of-view	Measured - Inset: Instantaneous 18 degrees by 24 degrees horizontal. Background: Instantaneous 48 degrees vertical by 95 degrees horizontal.
Viewing volume	Measured - 15 mm pupil centered on each eye.
Brightness	Measured - Peak highlight brightness 21 foot-Lamberts (using CAE method).
Contrast ratio	Measured - Left eye 22.8 to 1, Right Eye 27.5 to 1.
Collimation	Measured - 20 feet. Can be set to match HUD, normally >10 meters.
Geometric distortion	CAE Spec - Average 1.3 degrees overall horizontal and vertical.
Color Convergence	CAE Spec - < 0.1 degrees.
Video signal-to-noise	Not Available.
Sweep signal-to-noise	Not Available.
Grey scale	CAE Spec - Continuous grey scale, 8 bits/color.
Colors	Full color.
Blemishes	CAE Spec - Blemishes due to fiber optic cable used for image transmission between CRT and helmet display, < 0.1% in quality area. Black spots, due to cable strand breakage, throughout the field of view, were noted.
Swimming	None.
Spurious images	None.
Image continuity	Measured - Individual eyepiece displays, overlapping 28 degrees in center of image field of view.

DISPLAY ATTRIBUTES (Continued)	
Area-of-interest blending	Dual Acuity Merge Processor electronically combines background and inset before sending combined video signal to CRT rasters for each eye.
Display Transmission	Measured - Helmet mounted display approximately 5.1% transmission both eyes.
HUD/Display focus	Measured - Both collimated at 20 feet.
HUD/Display correlation	Measured - As accurate as head position sensing permits (less than 0.1 degrees in HUD area).
Refresh rate	60 Hertz.
Projector slew rate	N/A.

IMAGE GENERATOR ATTRIBUTES	
View Point	CAE Spec - 2 viewpoints, 4 channels, 1 background/one inset electronically combined per eye.
Translucency	CAE Spec - 33 levels per polygon; 33 levels per texture.
Texture	CAE Spec - 24 Megapixels for macro texture [1536(128X128)] with texture paging capability (*), 1.5 Megapixels for micro texture [96(128X128)]. Full color RGB and transparency. All texture can be dynamic and photograph. * Texture paging not integrated at MFS.
Polygons	CAE Spec - 4000 polygons at 60 Hz per channel.
Raster lights	CAE Spec - 1000 Light Points per channel. Trade 2 to 1 for polygons.
Calligraphic lights	N/A.
Moving models	CAE Spec - 48 moving models available (*) for dual acuity system. * Currently 16 moving models integrated at MFS.
Ambient light	CAE Spec - Continuous time of day available (*). * Only day scene integrated at MFS.
Haze/Visibility	CAE Spec - Available zero feet to clear sky; Not integrated at MFS.
Clouds	CAE Spec - Available; Not integrated at MFS.
Horizon	Yes.
Thunderstorm/Lightning	CAE Spec - Available explosives, flares, etc.; Not integrated at MFS.
Special effects	CAE Spec - Available; Not integrated at MFS.
Sun angle shading	CAE Spec - Available - Sun azimuth and elevation is specified with continuous time of day. Shading will change according to sun angle (*). * Not integrated at MFS.
Surface shading	CAE Spec - Available, can be applied to any polygon; Not integrated at MFS.
Anti-aliasing	Yes. 32 subpixels.

DATA BASE ATTRIBUTES	
Visual range	No preferred maximum; 21.3 km for West Coast Database.
Level-of-detail ranges	No Pre-defined maximum. West Coast Database levels used are: Finest LOD: 1.07 polygons/km^2 extend from viewpoint to 4.9 km. Fine LOD: 0.533 polygons/km^2 extend from 4.9 km to 10 km. Medium LOD: 0.266 polygons/km^2 extend from 10 km to 14.4km. Course LOD: 0.1333 polygons/km^2 extend from 14.4km to 21.3 km.
Occultation levels	CAE Spec - No Limitation. Equal to the number of polygons.
Distracting effects	30 Hz overload condition.
Update rate	CAE Spec - 60 hertz.
Transport delay	CAE Spec - 59.2 milliseconds.
Positional range and accuracy	CAE Spec - 0.5 mm.
Crash detection	CAE Spec - Yes. Collision of ownership with terrain, culture, and other moving models. Available; Not integrated at MFS.
On-line data base	CAE Spec - Up to 200,000 polygons per eyepoint (FOHMD).
Geographic location	A subset of the AV-8B West Coast Database; 4X7 degrees. N32-36 degrees, W112-119 degrees.
Scene density	Finest LOD: 1.07 polygons/km^2 extend from viewpoint to 4.9 km, Fine LOD: 0.533 polygons/km^2 extend from 4.9 km to 10 km. Medium LOD: 0.266 polygons/km^2 extend from 10 km to 14.4 km. Course LOD: 0.1333 polygons/km^2 extend from 14.4 km to 21.3 km.
Model level-of -detail	Universal features 2 LODs, moving models 3 LODs.
Moving models	FA-18, MIG-23, ZSU-23, Maverick, SAM site, truck, red and white markers, Nimitz, Destroyer.
MODEL LIBRARY	
Airfield library	El Toro, Miramar, 29 Palms, El Centro, Camp Pendelton, Palm Springs, Ocotillo, Norton, North Island.
Light models	Cultural lights, airfield lights, runway approach lights, etc.
Data base size	1472 (15km X 15km) tiles = 331,200 square Kilometers.
Airfield area size	As per airfield, included in geographic database.
Low altitude area size	3 X 3 degrees; N32-35 degrees, W115-118 degrees
Air to ground area size	Bomb targets at N32-55 degrees, W115-43 degrees.
Texture maps	24 Megatexels for macro texture [1536 (128X128)] with texture paging capability (*), 1.5 Megatexels for micro texture [96(128X128)]. * Texture paging capability not integrated at MFS.
Accuracy	0.5 mm.
Polygon allocation	Not Available.
Source data	Database converted from Lockheed-Martin CompuScene IV/A AV-8B West Coast Database source code to run on CAE MAXVUE™. Lockheed-Martin data DMA DTED/DFAD Level 1. 1:50,000 maps and 1:250,000 JOG charts used.