THE UTILITY OF HELMET-MOUNTED VISUAL DISPLAYS FOR TACTICAL AIR CREW TRAINING

Parker R. Goodwin and Samuel N. Knight
CAE-Link Corporation
Binghamton, New York

ABSTRACT

Much of today's training system development emphasizes lowering procurement and life-cycle costs. Also, there is a strong desire to evolve to truly mobile systems. At the same time, however, the services wish to retain the visual display performance previously achievable only with bulky dome or mirror systems. This paper addresses helmet-mounted display technology as an effective solution for the visual display requirements of tactical air crew training. The basic similarities that exist in the training requirements for both fixed wing and rotary wing tactical training systems will be discussed. This evaluation will also consider the variances in mission types, mission environments, mission equipment, crew configurations, and cockpit displays and the impact of these differences on training requirements. Subsequently, the paper will discuss the adaptability of the helmet-mounted display in meeting the training requirements. The possible physiological impact of the display's weight on the heads of flight crew members will be addressed as well as the perceived fragility of the display system. The impact of the display system on the facilities required to support the flight simulation system will also be considered. A final discussion of the trade-off of training requirements versus display system capabilities will be provided to demonstrate that the helmet-mounted system is an extremely cost-effective visual display for tactical air crew training.

ABOUT THE AUTHORS

Parker Goodwin is a Training Analyst with CAE-Link Corporation of Binghamton, New York. Mr. Goodwin served in the U.S. Army from 1968 to 1988 and retired as a Chief Warrant Officer Four, Master Aviator. Since his arrival at CAE-Link in January of 1989, Mr. Goodwin has conducted analyses to determine the design requirements for training systems to support advanced technology aircraft, including the First Team's RAH-66 Comanche. He holds an Associate of Science from the University of the State of New York, a Bachelor of Science from the State University of New York, and is continuing his higher education at the State University of New York at Binghamton.

Samuel N. Knight is a Senior Staff Scientist with CAE-Link Corporation in Binghamton, New York. Mr. Knight is the corporation's chief scientist for Distributed Interactive Simulation Initiatives and is the Principle investigator for the Multiple Simulator Networking (MULTISIM) IR&D program. He is also a technical advisor on numerous projects including the Comanche program. He was previously the Tactical Systems Lead Engineer throughout the conceptual and development phases of the prototype AH-64 Combat Mission Simulator. During Desert Storm he was the Program Engineer for the AH-64 Desert STAARS program. He has over 22 years experience in visual and tactical systems simulation. He has a Master of Electrical Engineering degree from Cornell University and a B.S. in Electrical Engineering from Clarkson University. Mr. Knight has published work in the areas of tactical simulation, simulator networking, simulator fidelity, and mission rehearsal.

THE UTILITY OF HELMET–MOUNTED VISUAL DISPLAYS FOR TACTICAL AIR CREW TRAINING

Parker R. Goodwin and Samuel N. Knight
CAE–Link Corporation
Binghamton, New York

TACTICAL AIR CREW TRAINING CONSIDERATIONS

Tactical flight conditions are the same for all participants in any conflict. A participant's branch of service or national emblem will not have any influence on the weather or ambient light level. If fog rolls into the area of operations, everyone must deal with a reduction in visibility. When night falls all contestants must operate in the dark. It is this very sameness that drives the requirement to train. Even if an aviation crew has a technically superior weapon system, they will not necessarily possess a superior war fighting capability until they are trained to exploit the system's full capabilities.

If one set of tactical air crew is trained to operate more efficiently in an environmental condition than their opponents, they achieve a tactical advantage. The opponent must train toward equal efficiency within that environment or concede control of it. The flight conditions can vary tremendously. Day, night, poor weather, high altitude, low altitude, Nap Of the Earth (NOE), and over water are representative, but are by no means a complete list of possible conditions. The category and capabilities of their aircraft provide individual tactical air crews with different options, but will not change the flight conditions.

The real question here is not should we train, but rather how to best present the training. We accept that a training system intended to prepare flight crews for operations within a tactical environment must be capable of simulating that environment. The visual system used for training tactical flight crews must meet two difficult criteria: correct presentation and availability. The correct presentation of visual data is very important to the training of tactical crews in order to reinforce correct habit patterns. If a pilot is taught to look over his shoulder in the aircraft, he should be able to look over his shoulder in the trainer. The visual system should also be available to support the flight crews where and when it is needed. The best training

system in the world is useless if it is not available when required.

VISUAL SYSTEM REQUIREMENTS

The basic skills that a tactical air crew must master fall into three broad categories: flight and navigation skills; weapon and sensor skills; and crew coordination skills. The ability to acquire and sustain these skills is strongly influenced by the ability of the crew to interpret visual stimuli, both out–the–window and in–cockpit. Maintaining situational awareness, one of the most difficult tasks for a tactical flight crew, is based on the ability to visualize a constantly changing four-dimensional picture.

Tactical flight crews survive by responding properly to a continuous flow of visual stimuli. The visual system that supports tactical flight training should present all the required portions of that visual flow as naturally as possible.

The exact requirements of a visual system are determined by analysis of the training that the visual system must support. A training analyst will consider many things during this process. He will look at the mission, the environment, the capabilities of the weapons platform, and the requirements for night vision devices and Head Up Displays (HUD). He will also consider the aggressive nature of tactical flight and the need to use in–cockpit displays. After considering these and many other variables, the analyst will evolve specific visual system requirements to support an effective simulation of the aircraft and its mission.

Tactical missions are composed of tasks that are basically the same from aircraft to aircraft. These similarities in mission tasks precipitate visual system requirements that are common to aircraft that look very different.

All tactical air crews must fly to their target area, often at low level or nap–of–the–earth, without being surprised and becoming unwitting targets. After arriv-

ing in the target area those crews in the attack and fighter communities must also acquire the target, identify the target, and place steel on that target. All crews should also maintain situational awareness, that constantly changing picture of the tactical disposition, movement, probable actions, etc. of all participants, friend and foe, that could influence or be influenced by the crew.

Fixed Wing Requirements

In the fixed wing community there is normally a requirement for large fields of view and even larger fields of regard. A field of view is the area that can be instantaneously viewed by the crew member. A field of regard represents the area that my be observed by moving the field of view. A study conducted by R.V. Kruk and D.W. Runnings at the USAF Human Research Laboratory in 1989 indicated that a 66.5° X 127° field of view, with a field of regard limited only by the aircraft structure, was acceptable for ground attack, but the crews wanted a larger field of view for air combat. The crew is trained to constantly look for information, both visually and with their sensors. To be tactically effective, they must try to see above, below, and if possible, behind their aircraft to remain aware of what is going on around them.

The aggressive eyes-out maneuvering associated with tactical flying drives the requirement for large fields of view. A pilot that is about to pull vigorously into a different area of the sky wants to be sure that the area is not already occupied. Also, a pilot engaged in air-to-air combat wants as full a view as possible, especially when he is forced into evasive maneuvers.

Spatial resolution is another important factor in display selection. The exact resolution required for training is also the result of analysis. The study mentioned above used a fiber optic helmet-mounted display with a 18.5° X 25° high resolution insert. That insert was capable of providing 1.5 arc minutes resolution. The final resolution requirement varies with the mission of the aircraft and any technical approaches used to enhance specific portions of the visual scene.

Visual systems are also required to present in-cockpit visual displays. Modern aircraft possess any number and type of tactical displays. Some aircraft have TV, while others have Forward Looking Infrared (FLIR). It does not matter if the aircraft is flown by a single pilot or a crew. If the aircraft presents visual information in the cockpit, the trainer must present the same sort of information. The visual system must also

be capable of simulating any HUD or night vision devices used by the flight crew.

Rotary Wing Requirements

In the rotary wing community there is the same desire for large fields of view and regard. Rotary wing crews maintain the same sort of situational awareness and perform the same sort of visual and sensor searches as their fixed wing counterparts. The visual requirements analysis performed for the RAH-66 Comanche identified 60° X 120° as the preferred field of view and 110° X 330° as the field of regard.

Maneuvering requirements drive large fields of view for the rotary wing world just as they do for the fixed wing. While helicopter crews do not travel as far when they maneuver aggressively, they tend to start the maneuver in very close proximity to the ground. Helicopter pilots also must be insured that their intended flight path is not through a tree or hill.

Determining the exact resolution requirements for helicopter visual systems follows the same type of analysis as for the fixed wing requirements. The requirement to maneuver between obstacles during nap-of-the-earth and to acquire and identify targets tends to drive the resolution requirements toward the higher end.

While the same requirement to present night vision devices and HUD information exists for the helicopter crews, there is one area that is distinctly different. Modern attack helicopters often incorporate helmet-mounted sighting systems. This provides the crew the capability to aim and fire two weapon systems simultaneously. This ability generates a visual requirement for individual eye points for each crew member. Helmet-mounted sights are also under development for fixed wing attack and fighter aircraft. This will lead to a similar fixed wing visual requirement in the near future.

The cockpits of the helicopters also have visual displays that must be presented to the crew.

Helmet-Mounted Displays

We have determined that the visual requirements for tactical training of flight crews are similar. As a general rule, it can be seen that the tactical training system visual requirements will run to large fields of view and large fields of regard. The resolution is the result of analysis, but it is often high. Accurately represented HUDs and helmet-mounted sighting systems are normally required for aggressive eyes-out, hands-on- grips tactical flight and accurate munitions

delivery. The ability to perform night vision device training is often a requirement. Cockpit displays are also a part of the visual environment and must be available for use by the tactical air crew. All of these considerations influence the requirements of the visual system for a tactical training system.

The display system is especially important since, to a large extent, it dictates the available field of view, field of regard, spatial resolution, and perceived brightness. Helmet–mounted displays are rapidly becoming a leading technology in the simulation industry's attempts to meet all of these requirements.

Helmet–mounted displays are particularly adept at teaching the scanning techniques that support situational awareness. The helmet–mounted visual's field of regard is limited only by the mask of the simulated aircraft. They can also provide large fields of view with high resolution inserts. A good helmet–mounted display may have 1.5 arc minutes of resolution, while a good dome has 10 to 15 arc minutes of resolution. This allows the crew member to look where he would normally look and see distant target imagery with fairly realistic resolution. There are no artificial limits on the crew's field of regard. The physical limits of the aircraft are, however, present in the cockpit mask. The cockpit mask is a three–dimensional presentation of the aircraft and its canopy or windows' configuration. As the crew looks around they see the fuselage, wings, canopy rails, etc. of their aircraft.

A helmet–mounted display study at Williams AFB noted that there is some loss of peripheral cuing with helmet–mounted displays. Some analysts believe, however, that the loss of this cuing will cause the flight crews to scan more actively with head movement. Keeping your head moving is one of the basics of tactical flight. Forcing crews to turn their heads to compensate for the lack of peripheral cuing may turn out to be a very small price to pay for the complete field of regard.

The HUD may be presented in two different ways with a helmet–mounted display. A HUD or a representation may be mounted on the dash and used as it normally would be in the aircraft or the HUD data may be represented directly on the helmet–mounted display. In all fixed wing aircraft and some attack helicopters the HUD is mounted to the dash and the first option may be more appropriate. In the newer U.S. attack helicopters, however, the HUD symbology is displayed on the crew member's helmet. These individual HUDs also drive a requirement for individual eye–points for accurate firing solutions, especially helmet–aimed off–axis engagements. In those situations, a helmet–

mounted display is often a more cost–effective solution than pursuing an alternate approach of providing separate crew stations and visual systems for each crew member.

Simulation–based training for night vision devices may also be accomplished in two ways. The actual device may be used to view a darkened visual display. The other option is to represent the field of view and appropriate resolution of the night vision device on a helmet–mounted display. If the training system uses the actual night vision device, the field of regard is limited to that of the darkened visual display. The user's logistics must support the increased use of the tactical crew's flight equipment or provide night vision devices, with the required support, for training use only. If, however, the field of view and resolution of the night vision device is replicated on the helmet–mounted display, there is no increase in logistics. The crew member will also have the field of regard appropriate to his aircraft.

In–cockpit displays often present crucial information and are an important part of the visual requirements for tactical flight training. If the training system uses a helmet–mounted visual, then it is necessary to provide a means to enable the crew member to observe both the helmet imagery and the cockpit displays.

If the training system's visual requirements are met by smaller fields of view, it may be possible for the flight crew to look around the helmet display optics. This is the same technique used by pilots wearing Night Vision Goggles (NVG). If the field of view requirement is large enough, the crew member will not be able to look under the display and should view the cockpit through the mask. Since there is some loss of transmissivity through the helmet optics, this requires that the in–cockpit displays be bright enough to be viewed through the mask. Paul Van Hemel noted in his report on the Tornado training system that the crews would still try to look around the helmet–mounted display, even though a cockpit mask was in use.

Available helmet–mounted visual systems come in two basic types; Fiber Optic Helmet–Mounted Displays (FOHMD) and Cathode Ray Tube (CRT) or liquid crystal displays. The visual scene presented on either type of system is generated by a Computer Image Generation (CIG) system. The visual scene presented on the FOHMD is projected in a closed environment and transmitted over fiber optic bundles to a set of optics called "pancake windows". The CRT or liquid crystal scenes are also developed by a CIG, but the

information is transmitted electronically, rather than optically, for viewing. The CRT or liquid crystal displays may be directly viewed or observed through optics. Each has physical characteristics and display capabilities that impact their ability to answer the visual requirements of specific training systems.

CHARACTERISTICS OF HELMET–MOUNTED DISPLAYS

Much of today's training system development emphasis is on lowering procurement and life cycle costs. There is also a strong desire to evolve to truly mobile systems. At the same time, however, the services wish to retain the visual display performance previously achievable only with bulky dome or mirror systems. Helmet–mounted displays are particularly adept at answering the dual challenge of mobility and required fidelity.

Helmet–mounted displays are obviously the smallest and easiest visual system to transport. The capability to present the required fidelity does differ with the type of helmet–mounted visual display.

FOHMDs have larger fields of view and higher resolution than the CRT displays, especially if a high resolution insert is used. The CRT displays are only capable of low to moderate fidelity, but are less expensive than the FOHMD. The final selection would be dependent on the training requirements that must be met.

The aggregate weight of the system and the physical stress that it places on the head and neck of the crew member is a concern. Manufacturers are constantly striving for lower weight and better balance. We also must remember that some helmet–mounted displays are in use in actual aircraft and some crews fly significant portions of their training with these displays. The use of NVG is a good example.

The ANVIS–6 NVGs worn by U.S. Army and Air Force flight crews weigh 2.02 pounds with their battery pack and visor. The fly–away weight with a standard flight helmet is 5.5 pounds. Consider also that the crew member often adds an additional 8 to 12 ounces as a counterbalance (a maximum of 22 ounces is allowed). Many pilots normally fly with 6.25 pounds on their heads using the ANVIS–6; if they fly with modified AN/PVS–5 NVG it is closer to 7.5 pounds.

A recent study of the Tornado simulator preformed by Paul Van Hemel provides some input in this area. Less than 7% of the participants of the study mentioned helmet discomfort when using the head tracked system. Even though the helmet weight remained the same, the incidence of discomfort comments did increase by approximately 10% when an eye tracker was used for the entire mission. The eye tracker was a new addition to the simulator and may have made the participants more conscious of the display.

APPLICATION OF HELMET–MOUNTED DISPLAYS

The visual system requirements for training tactical air crews are dependent on the mission and equipment of those crews. Many mission and aircraft specific requirements have a strong resemblance across multiple missions and differing aircraft types since the types of tasks involved are similar. Crews must fly aggressively, often in close proximity to the ground. They must be able to navigate visually as well as electronically. Finally, they must acquire, identify, and engage their targets. These similarities call for large fields of view/regard and cockpit displays regardless of the service or nationality of the crew. The exact resolution requirements for the visual system are a function of training analysis.

Meeting the requirements of the visual system falls into two categories: the image generation (IG) system and the presentation medium. The final selection is the result of a series of trade offs between requirements, costs, and capabilities.

The trade–offs that determine which visual display system is selected must consider many things which go beyond training effectiveness and include such variables as facilities impacts, durability, and procurement costs.

Facility requirements and associated cost will have major impact on the final decision. The helmet–mounted displays are the smallest and lightest of all displays and have the least impact on facilities requirements. This is an extremely important factor when considering the development of a deployable training system.

Helmet–mounted displays are sometimes perceived as fragile and subject to breakage through normal use. They are, in fact, more fragile than a dome or Wide Angle Collimated (WAC) windows. They are put on and taken off by flight crews. Whether or not they will be damaged during normal use by tactical crews is the real question. What must be remembered is that these crews may normally put on and take off NVG or other forms of tactical helmet–mounted displays. In any case, they are used to taking care of their gear with a minimum of abuse. Perceived fragility of the helmet–mounted display should be a consideration, not a discriminator.

CONCLUSIONS

The actual procurement cost of the helmet-mounted display is dependent on the visual system training requirements. Those requirements will determine which type of display is needed. Dr. Berbaum and Dr. Kennedy state in the introduction to their test plan for evaluating training potential for helmet-mounted displays, "This device may offer an alternative technology to more traditional multichannel simulation displays at a fraction of the cost but with the same or better spatial resolution and detail density."

All visual displays can accomplish tactical training of one sort or another. The real discriminator in this trade-off is availability. The best training value is determined by presenting the training where it is needed. Tactical crews cannot come to simulators during time of conflict. The trainers must be capable of going to the crews. The helmet-mounted display can meet the large field of view/regard requirements normally associated with tactical training. It can present high resolution imagery. But more importantly, helmet-mounted displays are small and lend themselves to mobility. They can go to the crews.

REFERENCES

"Experimental Evaluation Of A Tornado Simulator Modified With A Fiber-Optic Helmet-Mounted Display (FOHMD) And A 6-Degrees Of Freedom Motion Base", Paul E. Van Hemel, Ph.D., et al, February 21, 1992.

"A Helmet-Mounted Virtual Environment Display System", Cpt. Robert K. Rebo, USAF, December 1988.

"Low Level Flight Performance And Air Combat Maneuvering Performance In A Simulator With A Fiber Optic Helmet-Mounted Display", R.V. Kruk and D.W. Runnings, August 14, 1989.

"Plan For The Evaluation Of The Training Potential Of Helmet-Mounted Display And Computer Generated Synthetic Imagery", Kevin S. Berbaum, Ph.D. and Robert S. Kennedy, Ph.D., April 29, 1985.

"Flight Simulator: Advanced Wide Field-Of-View, Helmet-Mounted Display, Infinity Display System", R. Barrette, et al, September, 1990.

"Fiber Optic Helmet-Mounted Display for Full Vision Flight Simulation", Cpt. Caroline L. Hanson, et al, SID 1984.

"Wide-Field-Of-View, Helmet-Mounted Infinity Display System Development", CAE Electronics Ltd, December 1984.

"Low Cost Design Alternatives for Head Mounted Stereoscopic Displays", Stephen W. Martin and Richard C. Hutchison, Three-Dimensional Visualization And Display Technologies, 1989.

"General Operational And Training Visual Concerns", Cdt. Avi. Ir D. Agneessens, April 1988.

"Advanced Simulator For Pilot Training And Helmet-Mounted Display Configuration Comparisons", Robert R. Woodruff, et al, May 1985.