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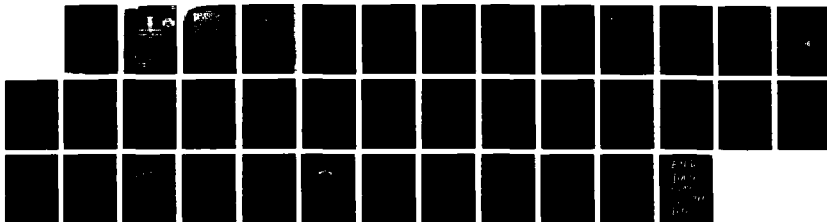
THE ALL-ASPECT GUNSIGHT: RETURNING SHORT RANGE COMBAT
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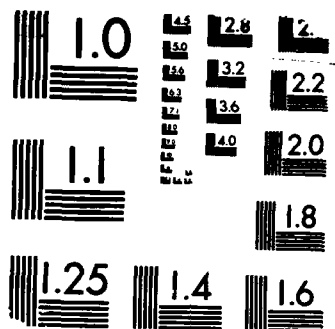
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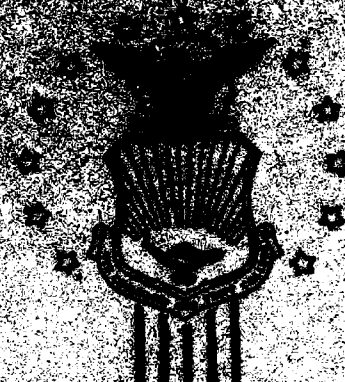
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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

THE ALL-ASPECT GUNSIGHT; RETURNING
SHORT RANGE COMBAT EFFICIENCY TO THE
F-15

MAJOR EDWIN R. LOSKILL 88-1625

"insights into tomorrow"

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REPORT NUMBER 88-1625

TITLE THE ALL-ASPECT GUNSIGHT: RETURNING SHORT RANGE COMBAT
EFFICIENCY TO THE F-15

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Submitted to the faculty in partial fulfillment of
requirements for graduation.

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PREFACE

The author first became interested in the concept of an accurate, all-aspect gunsight while attending the USAF Fighter Weapons School at Nellis AFB, Nevada in 1983. During the course of instruction in aerial gunnery, considerable study was devoted to identifying and minimizing gun employment limitations resulting from the F-15 Lead Computing Optical Sight's (LCOS) mechanization. Later, while assigned as the Chief of F-15 Weapons and Tactics Development for Strategic Air Defense, the author was the project manager of several formal Tactical Air Command test projects which again highlighted the F-15's loss of combat capability due to the LCOS's lack of accuracy and all-aspect capability. These projects' final reports and the less than sterling results from annual gunnery meets served as catalysts for raising the priority of equipping the F-15 fleet with an accurate, all-aspect gunsight, specifically the General Electric Corporation's Enhanced Envelope Gunsight. Even though this gunsight is currently being fielded on the advanced F-16C, no funds have yet been allocated toward an F-15 retrofit. The author's purpose in writing this paper is two fold: to explain the combat limitations of the LCOS-equipped F-15 and to identify the significant tactical advantage offered by the EEGS.

The author is grateful to the following individuals for assistance in preparing this paper: Major Steve Gress, Air Command and Staff College; Mr. Gene Tye and Mr. Jeff Watts, General Electric Corporation's Aerospace Control Systems Department; and Ms. Elizabeth Calloway, Headquarters, Tactical Air Command/DOA.

ABOUT THE AUTHOR

Major Loskill is a fighter pilot with over 1,000 hours in the F-15 Eagle. He is a graduate of the F-15 Fighter Weapons School and is an expert in F-15 weapon systems and tactical employment. He holds a B.S. Degree in Engineering Mechanics from the USAF Academy and is currently working on a M.S. Degree in Personnel Management. Prior to attending Air Command and Staff College, he was the Chief of F-15 Weapons and Tactics Development for Strategic Air Defense at the 475th Weapons Evaluation Group, Tyndall Air Force Base, Florida. As such, he developed and flight tested gun attack tactics against bombers, cruise missiles, and fighters. During these tests Major Loskill quantified many of the limitations of the F-15 Lead Computing Optical Sight (LCOS) gunsight. His two year research into the F-15's need for an advanced, all-aspect gun fire control system included studies with General Electric Corporation's Aerospace Control Systems Department and McDonnell Douglas' Simulation Department. These studies yielded the development of gunnery tactics and training techniques which are published in three multi-command tactics manuals, two articles in the Fighter Weapons Review, and three tactics development final reports.

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EXECUTIVE SUMMARY



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"insights into tomorrow"

REPORT NUMBER 88-1625

AUTHOR Major Edwin R Loskill, USAF

TITLE THE ALL-ASPECT GUNSIGHT. RETURNING SHORT RANGE COMBAT EFFICIENCY TO THE F-15

I. **Purpose:** To identify the F-15's loss of efficiency in the short range, visual combat arena and establish the all-aspect Enhanced Envelope Gunsight as the solution.

II. **Problem:** The F-15 is unable to achieve kills quickly or efficiently in highly dynamic and unpredictable close-in combat due to the time and maneuvering required to employ its gun. This short range armament deficiency is attributable to the limited capabilities of the F-15's Lead Computing Optical Sight (LCOS). Attempts to employ the LCOS in combat scenarios usually equate to long engagements and subsequent loss of the F-15 from unobserved adversary attacks.

III. Discussion and Data: Minimum range limitations of missiles, advancements in electronic combat measures, infrared countermeasures, stealth technology, and tactics all indicate the need for a gun capability to point, shoot, kill, and separate to avoid the turning fight or win quickly in a close-in visual fight. The F-15 currently lacks this capability due to the time and maneuvering required to employ the LCOS. This time and maneuvering causes the pilot to lose his sense of orientation relative to his wingmen and other threats thereby directly reducing his ability to survive. The limited capabilities of the LCOS prompted Tactical Air Command to levy a formal requirement to develop an all-aspect gunsight system. The Enhanced Envelope Gunsight (EEGS) is the result of that development effort. It expands the gun envelope to all practical target aspect angles with or without a radar lock-on. It includes a means for accurate assessment of the simulated gunshots taken in daily simulated exercises as an integral part of the sight. EEGS increases the effective envelope of the gun by more than 3-to-1. Time-to-kill, a key ingredient in aerial combat, is reduced over 65%. EEGS combines the agility and advanced avionics of the F-15 with the unique skills of the trained pilot to provide a force multiplier effective in high threat environments characterized by dense ECM, IRCM, and threat fighters.

IV. Conclusions: F-15 pilots will remain unable to achieve combat effectiveness in the close-in combat arena unless its fire control system is updated with the new technology and capabilities of EEGS. Today, if an F-15 pilot decides or is forced to engage for a gun kill, the long maneuvering time required to attain gunshot parameters for the LCOS gunsight will most likely cost him his life. The programed cost for fully implementing EEGS on the F-15 fleet is only \$29 million; slightly more than the cost of one F-15. This amount is extremely reasonable considering the fact that one of the F-15's short range missiles costs more than twice the amount required to retrofit one F-15 with EEGS. This figure is even more acceptable considering the F-15's increased killing capability using EEGS and the low cost of 20 mm ammunition. By realizing the probable outcome of a scenario where an LCOS equipped F-15 is engaged in a short range, turning fight, it can be seen how the total program cost of EEGS can be recovered in one combat engagement.

V. Recommendations: The Tactical Air Forces should equip their F-15s with the Enhanced Envelope Gunsight in order to ensure the F-15 fleet can either point, shoot, kill, and separate to avoid the turning fight or win it quickly.

Chapter One

INTRODUCTION

"Hostiles, 080 degrees, thirty-five miles, angels 10," F-15 pilot, Capt. King radioed to his wingman. He had just arrived at his air defense cap point anticipating another engagement with MiG 29 Fulcrums like the ones his flight fought yesterday. As Capt. King cross checks his radar scope he notes the Fulcrums' heading has changed, bringing them into his area of responsibility. "Commit," radios Capt. King. He shoves the throttles forward and is forced back in his ejection seat as the engines' afterburners ignite.

Cross-checking his radar and radar warning scopes he notes there are at least six MiGs, none of which are aware of the Eagles' presence. At the optimum range from the MiGs, Capt. King and his wingman fire long range radar missiles, then select short-range missiles, anticipating visual launches on the remaining MiGs. Suddenly, the MiGs break hard as the radar missiles reduce the MiGs' flight size by two. King cuts lose an AIM 9M on the lead MiG and scores another kill as the heat seeker explodes in the MiG's cockpit. One of the remaining MiGs turns hard to engage King but King anticipates the MiG's move and fires a high angle gun shot which misses. "Damn," King says out loud, cursing the limited capabilities of his gunsight. The MiG turns hard, forcing King to use precious time to maneuver to a position where his gun sight is more accurate.

King is now committed to a turning fight, knowing that the first fighter to run will soak up a missile from the other. This is costing King time, time which is reducing his situational awareness of the air battle around him. Twenty seconds have passed; King is close to a position where his gunsight will give him an accurate solution. King suddenly feels a searing pain in his left shoulder and side; his F-15 shudders from the impact of a missile fired by the MiG's wingman. Those precious seconds King used maneuvering for the limited envelope where his gunsight would be accurate allowed one of the MiG's wingmen to enter the fight unobserved and destroy King's F-15.

What you have just read is an account of one of the most common tactical employment deficiencies in today's air-to-air combat scenarios: the F-15 Eagle's inability to kill quickly with the gun in close-range combat. The F-15 possesses the capability to kill at medium and long ranges using high technology radar and heat seeking missiles. However, when aerial fights are reduced to short range, the F-15's short-range armament, namely the gun, can not be employed to kill quickly or efficiently.

The reason for this short-range armament deficiency is the limited employment envelope of the F-15's Lead Computing Optical Sight (LCOS) gunsight (2:--). With the LCOS system, a large sanctuary of airspace exists around a target inside short-range missile minimum range but outside the LCOS's effective envelope, see Figure 1 (8:24). If the adversary can turn to keep the F-15 in this sanctuary, he can increase the time duration of the

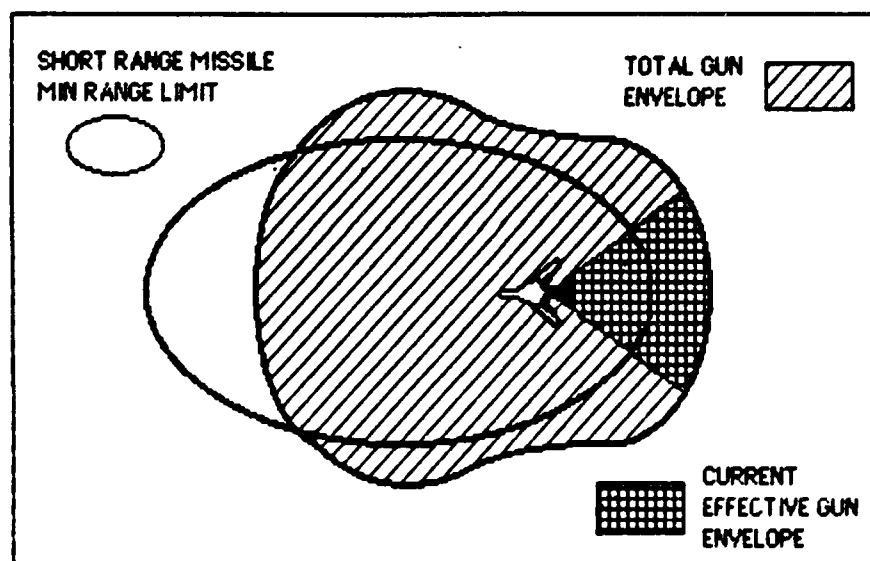


Figure 1. Short Range Sanctuary (12:--)

engagement, which in turn, exponentially increases the chances of an unobserved adversary destroying the engaged F-15. Replacing the LCOS with the all-aspect Enhanced Envelope Gunsight (EEGS) will increase the F-15's combat effectiveness by enabling it to kill quickly in the short-range

visual combat arena. The EEGS has already proven its ability to significantly improve short-range combat effectiveness in evaluation testing and day-to-day training in the F-16C. This effectiveness can be realized in the entire F-15 fleet for approximately the cost of Capt. King's F-15 that was destroyed due to LCOS employment limitations. It is therefore imperative that the EEGS retrofit for the F-15 be funded.

This paper supports the EEGS retrofit by examining five areas. First, an understanding of why the Eagle needs the capability to kill quickly in the short-range arena is presented. Second, a description of the current F-15 LCOS gunsight is provided to allow the reader an appreciation of its limitations. Third, a description of how the all-aspect EEGS is employed is given. Fourth, proof of the EEGS's capability to facilitate quick gun kills in highly dynamic and unpredictable close-in combat is furnished. Cost figures are also presented in this section. And finally, a summary and recommendation for retrofitting the F-15 fleet with EEGS is prescribed.

Chapter Two

THE NEED TO KILL QUICKLY

"Dramatic improvements in fighter weapons technology have generated changes in tactics and increased the importance of quick kills" (12:2). Reliable, highly maneuverable, all-aspect missiles like the AIM 9L/M provide point-and-shoot weapons systems that can quickly destroy an adversary. This quick-kill capability has become a key ingredient in aerial combat and is accentuated by the agility of the world's modern fighters in attaining or denying lethal firing envelopes, see Figure 2.

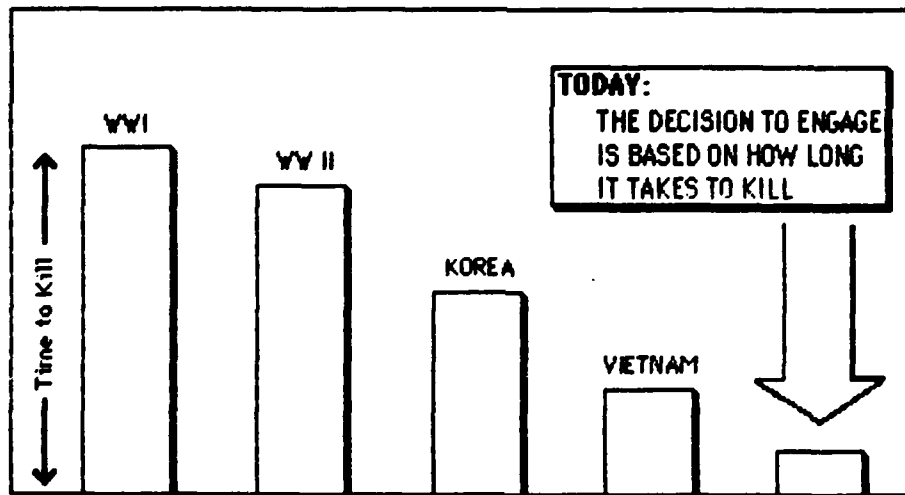


Figure 2. Time-to-Kill Has Become the Most Important Factor (9:4)

"Today the decision to engage is often based on whether or not a kill can be accomplished in a very short period of time" (9:4).

For example, if an F-15 pilot decides to engage for a gun kill, the long maneuvering time required to attain gunshot parameters with the LCOS gunsight has a dramatic effect on his survivability (10:--). When this pilot is engaged one-on-one, he dedicates his full attention to killing his opponent. As time progresses, his sense of orientation relative to his wingman and other threats degrades, thus reducing his situational awareness, see Figure 3.

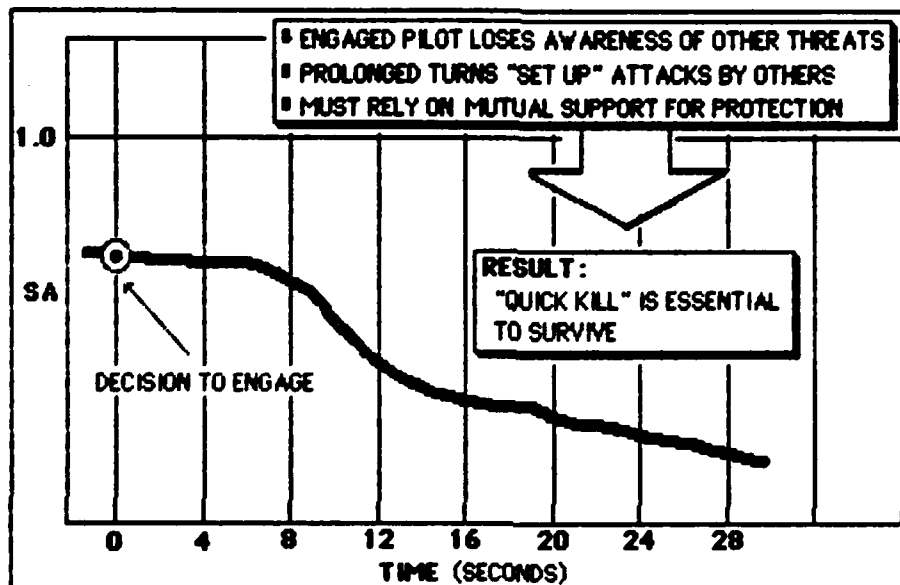


Figure 3. Situation Awareness Degrades During One-on-One Engagements (9:5)

Consequently, he must rely on his wingman to detect and destroy other enemy fighters that may enter the fight. The longer the engagement lasts, the more opportunities a threat (usually unobserved) has to attain a firing position. The pilot's key to survival in this situation is his capacity to kill quickly with an all-aspect gunsight (9:4).

Today, the lack of an all-aspect gunsight on the F-15 usually requires F-15 pilots to use defensively oriented tactics similar to those often used in Vietnam (high-speed, straight-line attacks with sophisticated schemes that allowed identification of hostile aircraft in time to launch from beyond visual

range) (3:BV-41). These tactics force pilots to avoid close-in combat in order to survive; thus, severely limiting the tactical effectiveness of the F-15 in combat. To comprehend the degree of capability lost due to the lack of an all-aspect gunsight, a description of the current F-15 LCOS gunsight is necessary.

Chapter Three

LCOS LIMITATIONS

The LCOS in the F-15 was developed with the assumption that the F-15 would be able to out-maneuver its opponents; therefore, it was mechanized to attain its best accuracy against tail-aspect, predictable targets in a guns only fight, and with a radar lock-on (5:3-2; 11:1). Unfortunately, these conditions seldom exist in aerial combat between modern fighters. This disparity between the LCOS's assumed employment parameters and actual target conditions results in sight errors and limitations of such magnitude that day-to-day gunnery training can not compensate for them.

Most fighter-versus-fighter gun shot opportunities are typified by high-aspect, high-closing velocities which render the LCOS unusable. Even if the F-15 uses its high turn rates to match the target's moderate line-of-sight rate, the LCOS aiming reference will display an underlead situation. This underlead situation will result in the F-15's bullets passing behind the target with errors up to 60 mils (this equates to 60 feet at 1,000 feet slant range) (6:2). What this all means to the F-15 pilot trying to take a typical gunshot is his perfect LCOS tracking shot will equate to a perfect miss!

Another example of the LCOS's incorrect mechanization concerns the target plane-of-motion (POM). If the target's POM is not the same as the shooter's POM, then the pilot has little hope of attaining hits on the adversary. The F-15 LCOS attempts to solve this POM problem by assuming that the F-15's POM is the same as the target's POM; a bold assumption considering there is no easy way for the Eagle pilot to ensure this condition exists unless the target is non-maneuvering or cooperative. Only a small change in bank angle or "G" is required to change the POM and foil the gun shot (5:6-7).

The F-15 Gun System Course Text, which is used to educate F-15 pilots in the proper use of the gun system, thoroughly describes the limitations of the F-15 LCOS system. This description has limited practical application;

however, because there is no way to quantify or assess gunshot errors in the air or during the review of gun camera film or video tapes after a mission. Therefore, weapons officers in fighter squadrons rely primarily on the placement of the LCOS reference pipper, see Figure 4, to ascertain the validity of attempted gunshots. This practice virtually reinforces poor gunnery techniques, many of which were graphically displayed during the world-wide-gunnery meet, William Tell '86. During the gun profile in this meet, twenty-four of the highest qualified F-15 fighter pilots attained a hit rate of only 30 percent against a 4 "G", 400 knot, towed target (7:1). Prior to drafting the meet's final report, the gun profile managers sent samples of the gun camera video to the Air Force Armament Laboratory (AFSC), Eglin AFB, Florida, for analysis of LCOS accuracy and observed training habits. In order to prevent biased comments, the lab was not told which gunshots had achieved hits. The senior analyst (10:2) who reviewed the tapes had been an instructor at the Fighter Weapons School at

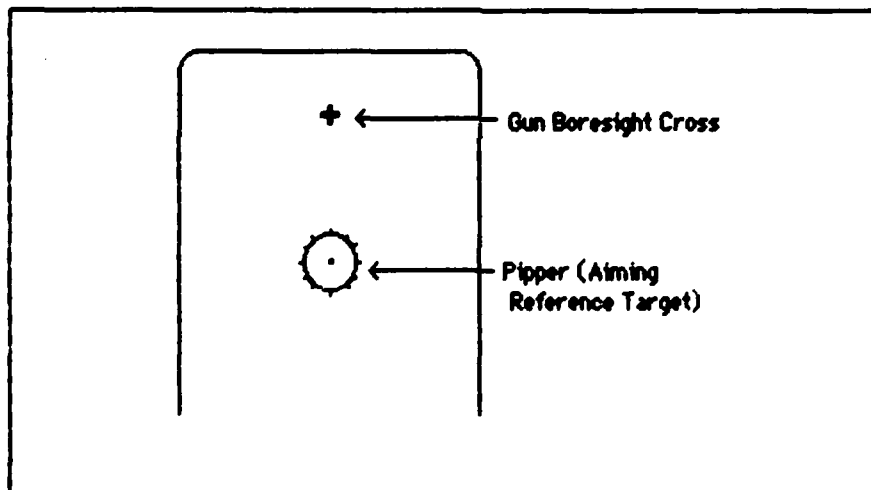


Figure 4. F-15 LCOS Head-Up Display

Nellis AFB, Nevada, and has over 20 years of experience flying fighters.

These were his observations:

TARGET PLANE (OF MOTION)

It appeared that on most of the non-tracking snap-shots (high aspect angle) the target was not in the proper plane-of-motion. (Editor's note: only one out of 24 attempts at snap-shots resulted in hits.)

SIGHT UNDERLEAD

There were four or five firing opportunities where tracking was outstanding. I don't know at this time if any hits were recorded on these particular passes but I would expect that there were very few. At best I could tell tracking G was on the order of 4.5-5.0 with moderate closure rate. The F-15 sight has an inherent 10-12 mil under-lead with these conditions and in only one case did it appear that the pilot allowed the pipper to drift ahead of the target.

The analyst later stated:

I did not intend to imply in the above remarks that the pilots were at fault. I flew fighter aircraft for over twenty years and instructed at the Fighter Weapons School for seven years. I know that fighter pilots do the best possible job with existing systems and preordained tactics.

This analyst felt the F-15 pilots performed as expected under the given conditions and LCOS limitations. He noted that more training would not necessarily solve the problems he had observed because, as stated previously, pilots' review of gunshot performance (gun camera training film and video tapes) largely reinforces poor gunnery techniques. Increased live firing exercises would not be beneficial either because the pilot does not know where the actual bullet stream is unless he scores hits, i.e., no error analysis is possible (13:--).

The LCOS system limitations discussed in this chapter were recognized as early as the mid-1970s. Pilots and technicians realized that a new gunsight was required which could combine the best features of conventional gunsight technology with a number of newly developed concepts to provide full use of the gun envelope with or without a target sensor lock-on. In addition to possessing deadly accuracy with full radar lock-on, the new sight would offer: all-aspect effectiveness without a radar lock, smooth sight transitions for radar lock/break-lock, assistance in getting "in the target's plane of motion", effective sight solutions even against a

competent adversary employing evasive maneuvers, and a unique training capability for greatly improved operational readiness through realistic and daily training (4:2). The new gunsight that these pilots and technicians envisioned is in production today and is known as the Enhanced Envelope Gunsight.

Chapter Four

ENHANCED ENVELOPE GUNSIGHT DESCRIPTION, & EMPLOYMENT

In late 1981, Tactical Air Command issued a Statement of Need (SON) for a gunsight which would correct the deficiencies being experienced with the Tactical Air Forces (TAF) current fighter gunsights. Senior TAF officials recognized a serious operational deficiency existed in employing current fighter LCOS gunsight systems in that they did not accurately predict bullet flight path at firing angles above 20-30 degrees (4:7). The SON was precipitated by an All-Aspect Gunsight Evaluation (AAGE-15) using a production F-15A at the Air Force Flight Test Center, Edwards Air Force Base, California and at the Air Combat Maneuvering Instrumentation Range (ACMI), Nellis Air Force Base, Nevada from 1 November 1979 to 17 February 1981. During this test, excellent accuracy and training usefulness of an on-board, dry-fire evaluation system was also demonstrated. The comparative evaluation of the LCOS against prototype all-aspect gunsights showed that pilot performance and gunnery effectiveness were significantly improved. Quantitative comparisons of effectiveness yielded improvements over the LCOS of 20 percent, 162 percent, and 387 percent in the rear-, beam-, and front-quarters respectively (6:3).

These demonstrated increases in gunsight capabilities and effectiveness resulted in the development and fielding (in the advanced F-16C) of the Enhanced Envelope Gunsight (EEGS) designed and produced by the General Electric's Aircraft Control Systems Department in Binghamton, New York. "The EEGS is a gunfire control system that combines the unique skills of the pilot, as a target sensor, with what ever information that is available from avionics sensors. A primary objective is to utilize, to the extent practicable, the full envelope potential of the existing gun, with emphasis on the regions where current missiles have minimum range limitations" (1:1). EEGS effectively solves the problems associated with the LCOS in combat and training by enabling quick, accurate, all-aspect gun employment coupled

with accurate assessment of that employment.

The EEGS consists of five sequential displays providing increasing levels of capability, see Figure 5. These levels of capability are determined by the fire control system's knowledge of target parameters: range, velocity, and acceleration. For example, if the radar has been locked-on for several seconds, EEGS transitions through Levels II, III, and IV to the highest capability, Level V, which contains a 4-mil pipper that indicates present gun aiming error.

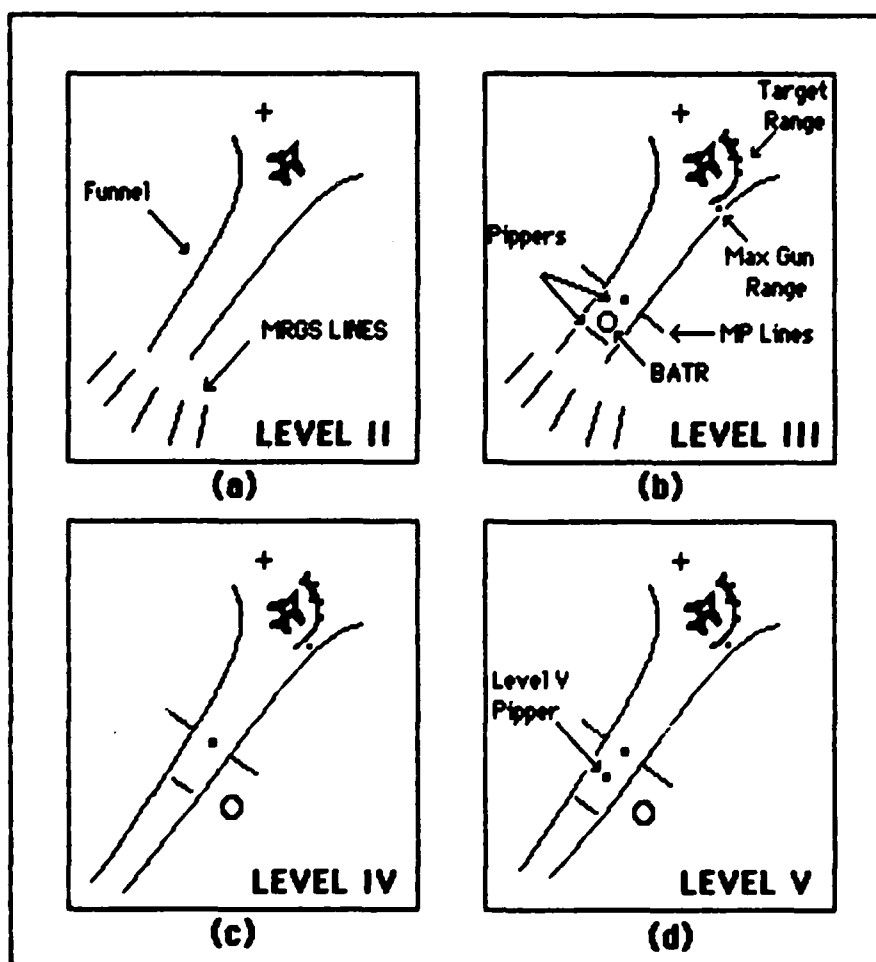


Figure 5. EEGS Head-Up Displays (8:3,4)

An accurate gunshot can be obtained by simply controlling the aircraft to superimpose this pipper over the target and firing. There are, however, a number of important reasons why the fighter pilot cannot rely solely upon this simple aiming reference (Level V) and why the lower levels of the sight are required:

- Gun firing opportunities occur most frequently in the highly dynamic situations where a radar lock-on may not be attainable in sufficient time to be useful.

- In multi-target engagements at low altitudes, a radar lock-on to the wrong target or the ground may occur.

- A radar lock-on may alert an otherwise unsuspecting target of the fighter's presence.

- Viable but fleeting opportunities for gunshots exist where the target is not in the Head-up Display (HUD) field of view.

- The Level-V Pipper (LVP) will be accurate only if the target has been on a predictable flight path for a few seconds and will remain so during the bullets' time-of-flight.

Additionally, graceful degradation is provided through all five levels should any radar inputs be denied by electronic countermeasures, maneuvering, or malfunction (8:--). The following is a brief explanation of those levels.

A. Level I. Level I consists of a cross displayed in the HUD which represents the point in space where the gun is boresighted. This symbol would be selected exclusive of all other symbology only in the event of a HUD failure. It is, however, an integral and important component of all other levels. The boresight cross is the primary aiming reference for shots that are taken with the target outside the HUD field of view. It is also employed in all levels for setting up firing passes and in cross-checking sight solutions (8:--).

B. Level II. Level II adds a sighting reference funnel and Multiple Reference Gunsight (MRGS) lines, see Figure 5(a). Level II's sighting reference funnel is primarily for rear-quarter and very high-aspect shots when the radar is not locked-on.

In rear-quarter shots, the pilot tracks the target by holding it within the funnel thereby accurately establishing the gun in the target's turning plane-of-motion. The funnel is essentially the turning plane of the gun with appropriate corrections for gravity drop, etc. The required lead-angle is

established by comparing the wingspan of the target to the width of the funnel. Uncertainty in the relative target wingspan is accommodated by distributing the firing burst along the length of the funnel. In very high-aspect shots forward of the beam, the pilot tracks the target at the lower end of the funnel and then fires when the target wingspan has increased to the width of the minimum funnel dimension (1:17-24).

The multiple lines in the lower region of the Level II display constitute the Multiple Reference Gunsight (MRGS). These lines are for use against high-speed targets at aspect angles from 60 degrees to 120 degrees. In these types of shots, the funnel is frequently compressed in the upper region of the HUD during the initial sighting period, whereas the target must be placed in the lower region of the HUD to ensure sufficient lead angle is available in the terminal stages of the pass. The pilot maintains the target under any of the lines, or between any two lines while closing to a minimum range (determined by aircraft "G" limitations). He then opens fire as the target begins to move up through the funnel. This accurately establishes the fighter in the target's turning plane-of-motion and achieves the maximum magnitude of lead angle that is available in the HUD (8:--).

C. Level III. When a radar lock-on to the target occurs, range is available and EEGS automatically transitions to Level III, see Figure 5(b). A target designator in the form of a clock analog of range is centered on the target with maximum gun range displayed as a dot on the periphery of the arc. Also, two pippers are now displayed in the funnel. The first is a small cross which depicts the lead angle for a constant velocity target. The second pipper is in the shape of a small bar which indicates the lead required for a target turning at a nominal maximum sustained rate. A pilot has no difficulty in estimating the required lead within these two limits. These two pippers make the pilot's job of estimating the required lead for given shot parameters extremely easy.

The dynamics of the funnel in Level III are the same as those in Level II. The MRGS lines are retained during Level III because the funnel may not be extended sufficiently to be of use in some high-aspect shots. These bars projecting from the sides of the funnel provide an indication of the out-of-plane maneuver potential of the target in one bullet time-of-flight. They are sighting references which the pilot can use to fire effectively at a target attempting an evasive maneuver i.e. moving out of the path of any rounds that are being fired (8:--).

D. Level IV. In a very short period after lock-on, the radar is able to measure target velocity and the system advances to Level IV, see Figure 5(c). The funnel retains its original shape, but it is now parallel to the target's plane-of-motion. It is extended in length and becomes much more controllable because it is a direct indication of lateral aiming error with very little pilot tracking or estimation of relative motion required. The MRGS lines are removed in Level IV because the longer, more controllable funnel is sufficient as a reference at all target aspects. Determination of the lead angle required for open fire is established the same as in Level II and III (1:46-49).

E. Level V. Several seconds after the transition to Level IV, target acceleration is sufficiently accurate for a transition to Level V, see Figure 5(d). When the range to the target is inside maximum gun range, a 4-mil, Level-V-Pipper (LVP) appears in the funnel and may be used to fire very precisely aimed bursts against a target on a predictable flight path. The funnel and the other symbology have the same significance as in Level IV. Although the LVP can be used in a tracking shot on a predictable target, this is not the recommended technique for achieving the full potential available in Level V.

If the radar has an error in target parameters, either because of tracking error or because the target has executed an evasive maneuver, perfect tracking of the target with the LVP will lead to a perfect miss. Instead of attempting perfect tracking, the pilot should use the maximum instantaneous turn-rate boundary (the small bar) as a measure of the target aircraft capability. If the target is judged to be turning at a rate substantially different from one where energy is conserved, the LVP relative to the lead-angle boundaries, provides an indication of the burst distribution that is needed, see Figure 6. Typically, the distribution will be no more than one or two target dimensions. However, the only practical way to make this judgment is through experience (8:--).

Figure 7 demonstrates how this experience is gained. It depicts an approach to a high-aspect shot in the forward region of the beam (about 120 degrees) and illustrates all the Level V symbology (except Bullets at Target Range [BATR] which will be explained later). The target is initially (a) at about 90 degrees aspect, 8,000 feet away, and turning hard into the attack (just like Capt. King's MiG 29 in the scenario at the beginning of this paper!).

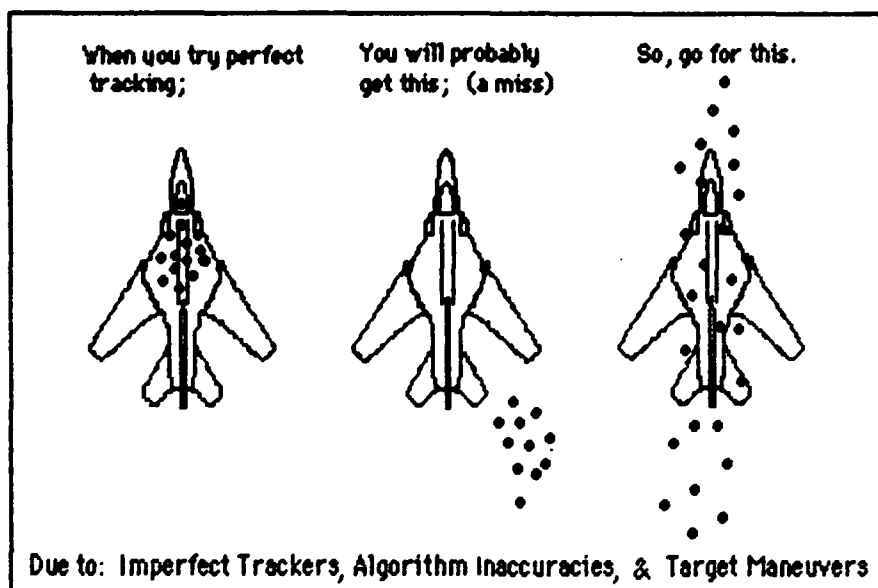


Figure 6. Perfect Tracking Versus Burst Distribution (12:--)

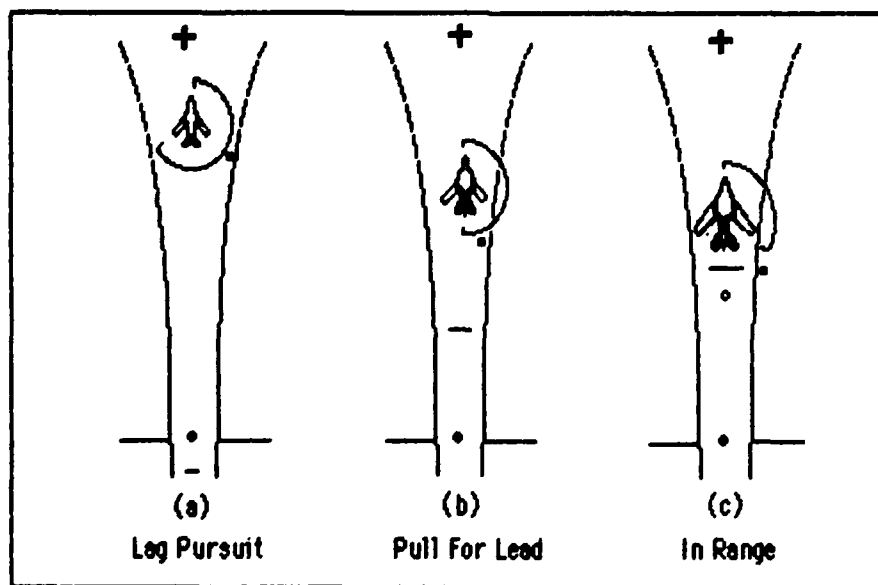


Figure 7. Level V Max Range Shot in the Forward Region of the Beam (1:51)

Maximum gun range is about 4,000 feet. A lag-pursuit approach (flying to a point behind the target) is appropriate at this time to ensure separation after the gunshot.

The amount of lag is determined by target range, aspect angle, rate at which the aspect is changing, range rate, and maximum gun range. As range decreases to near the maximum effective range of the gun (b), the aircraft's "G"s are rapidly increased to obtain sufficient lead for the earliest effective shot. Open fire (c) is with the pipper coming up from behind the target, creating a burst pattern from behind to forward of the target. A second burst pattern across the target in the reverse direction can be obtained at shorter range during the disengagement as the gun goes from overlead to underlead (1:51). The information required to kill a MiG in this type of gunshot is quite dynamic in keeping with the very nature of the engagement. "Practice with the high-aspect, high closing-rate geometry, and with the corresponding displays is essential in the development of the skills necessary to exploit the full potential of the system in these types of engagements" (8:--).

EEGS allows this practice by incorporating an integral capacity to display accurate simulation of gunfire. This capability is essential because it allows frequent and economically viable training against targets of realistic size and maneuverability. Timing in the control of burst initiation, and in burst length are critical skills would be difficult if not impossible to develop any other way.

Accurately simulated gunfire against aircraft targets of realistic size and maneuverability, flown by trained pilots is recognized as the primary method for the evaluation of air-to-air gunnery performance that is pertinent to modern air combat. It is important that fighter pilots have an appreciation of the accuracy limitations of their gunfire simulation because of the potential for negative training (158).

EEGS satisfies this requirement by displaying accurate simulated gunfire. When the gun is fired without a radar lock-on, simulated rounds are continuously displayed by the Firing Evaluation Display (FED) as pairs of dots at 0.1-second time-of-flight intervals, see Figure 8.

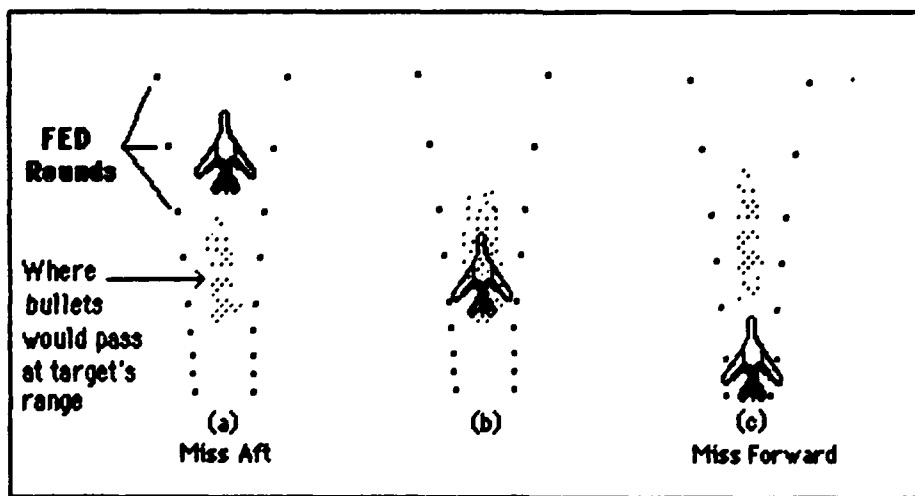


Figure 8. Firing Evaluation Display (FED)
Wingspan Reference (1:66)

These simulated rounds are separated by a nominal target wingspan of 40 feet. Actual rounds, if fired, would be midway between the dot pairs. The dot pairs move out through the HUD exactly as live tracers would appear, except for the lateral separation. Since each pair of dots is separated by exactly 40 feet (approximately the target wingspan), the bullets at target range on each video frame can be located by finding the pair of dots that subtend the same distance as the wingspan of the target.

Figure 8 consists of three frames of video from a firing attempt, (not necessarily sequential), which illustrate the evaluation process (1:59). The pair of dots adjacent to the target's wings in Figure 8(a) is separated by more than a wingspan so it is clear that the rounds at target range are passing in behind the target. In Figure 8(b), the dot pair adjacent to the target appears to be about the same width as the target, indicating that the rounds at target range are striking or passing very close to the target. On the final frame, Figure 8(c), it is clear that the rounds are passing in front of the target. Although an accurate measurement of hits cannot be obtained from this video sample, there is a high confidence that a significant number of hits would have resulted from a live firing burst (1:65).

When the radar is locked on the target, only those bullets passing through the target range are displayed on the HUD. These rounds are

displayed in the form of an 4-mil circle (gun dispersion), see Figure 9, and

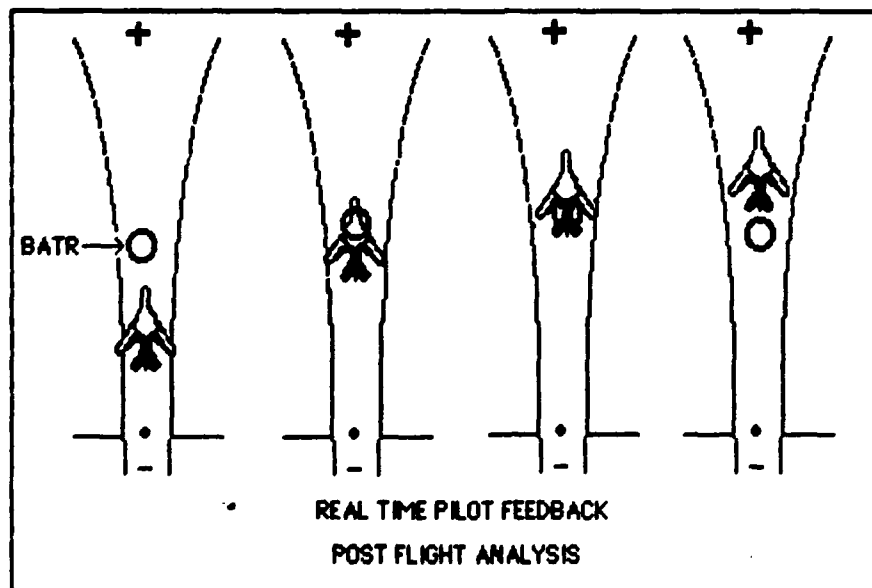


Figure 9. EEGS Bullets at Target Range (BATR) Display

are referred to as the Bullets at Target Range (BATR). The system interpolates between the simulated rounds in order to display a BATR symbol on each HUD and video frame that bullets are passing (or hitting) the target. This display provides the pilot with an immediate feedback of his miss distance (or hits) thereby greatly increasing his learning curve for gunnery skills and maintaining his combat proficiency and effectiveness through realistic daily training (6:--).

As this chapter's description of EEGS has shown, EEGS satisfies the F-15's requirement for fighting and quickly winning close-in engagements against modern fighters. Equipped with EEGS, the F-15 pilot can quickly achieve all-aspect firing solutions with or without a radar lock-on. His assessment of gunsight performance (actual or simulated) is displayed in real time, thereby increasing the development of skills necessary to kill and survive. With EEGS, the F-15 pilot is no longer limited to defensive tactics associated with the LCOS and therefore can be deadly in a short-range, visual combat arena.

Chapter Five

EEGS EFFECTIVENESS AND COST

EEGS initially proved its effectiveness in the All-Aspect Gunsight Evaluation (AAGE-15) conducted from 1 November 1979 to 17 February 1981. This evaluation determined the relative quantitative and qualitative effectiveness and potential of EEGS as compared to the F-15 LCOS in both simulation and live fire evaluations. This comparative evaluation showed that pilot performance and gunnery effectiveness were significantly improved using the new EEGS system, see Figure 10. During simulations, the

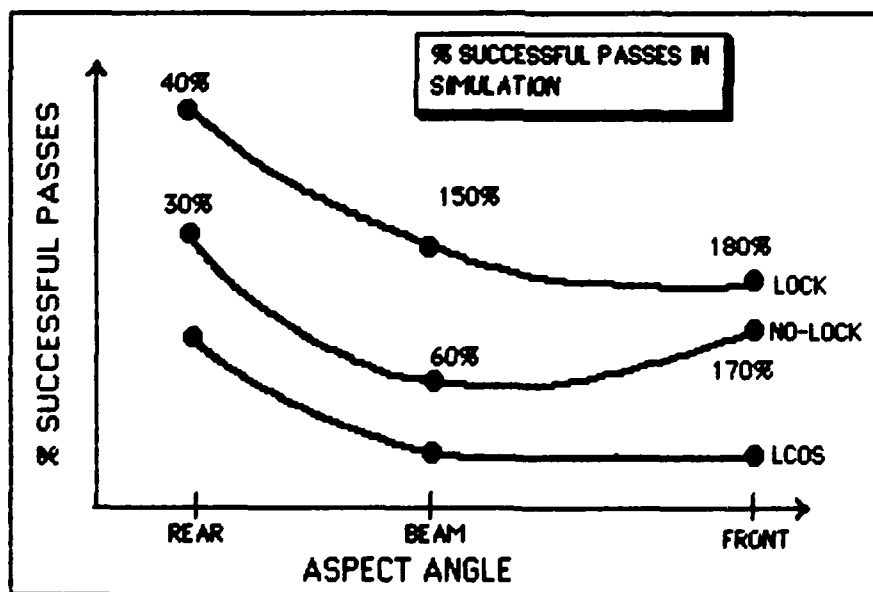


Figure 10. EEGS Increased Probability of Kill Over the LCOS (6:34)

increased probability-of-kill (Pk) over the LCOS was 30%/40% (radar locked-on/no-lock) in rear-quarter gun shots, 60%/150% in beam-quarter gun shots, and 170%/180% in front-quarter gun shots.

In the actual F-15 flight testing, EEGS improvements in Pk over the LCOS were 20%/0% (radar locked-on/no-lock) in the rear-quarter, 40%/160% in the beam-quarter, and 180%/387% in the front-quarter, see Figure 11 (6:6). These improved Pks reflect a direct increase in the F-15's ability to

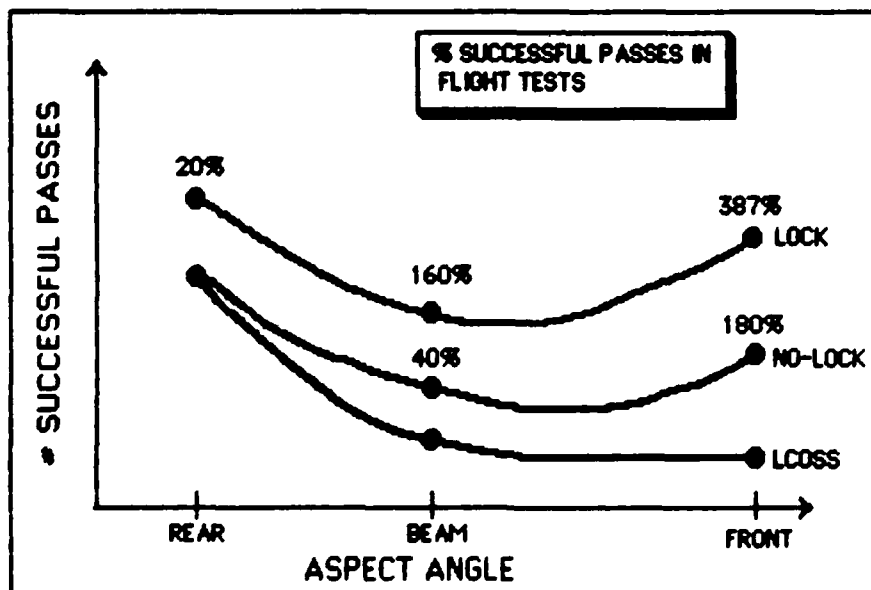


Figure 11. EEGS Increase in Probability of Kill Over the LCOS in F-15 Flight Tests (6:36)

survive in virtue of the shorter time required to attain lethal firing parameters. Reductions in time-to-kill of 43% were noted from 0-30 degrees aspect, 25% from 30-60 degrees aspect, and 67% from 60-75 degrees aspect, see Figure 12. These benefits and qualities of the EEGS were positively established using both preplanned and realistic simulated combat encounters and against both cooperative and noncooperative maneuvering targets (6:4).

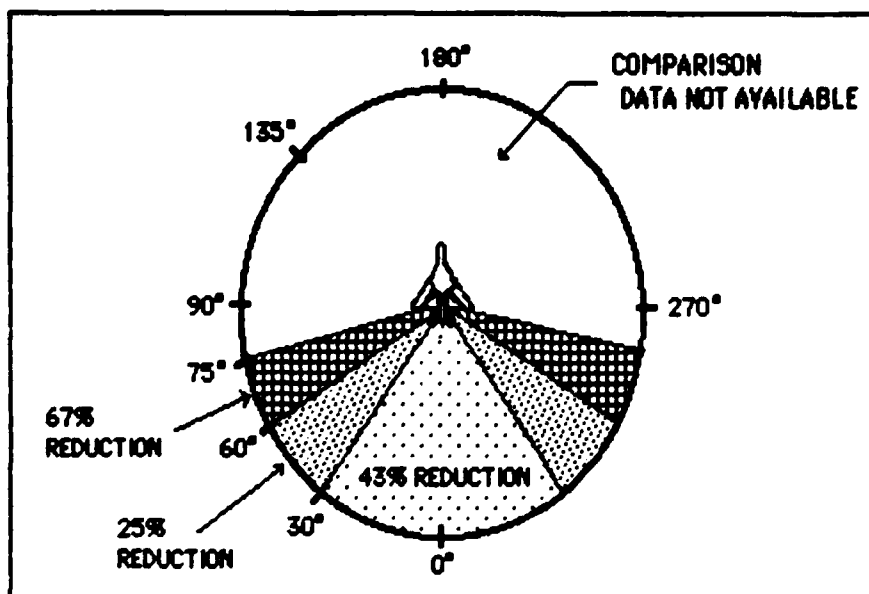


Figure 12. EEGS's Demonstrated Quick Kill Capability (12:--)

The accuracy and valuable training utility of the on-board dry fire evaluation systems, FED and BATR, were also demonstrated. The real-time feedback of both systems "were invaluable for training and provided substantial improvements over existing conventional sight training capability. The BATR greatly enhanced performance assessment and improved pilot performance levels, positively adding to training effectiveness" (6:4). These tremendous improvements in gun employment and daily training continue to be proven by pilots flying EEGS equipped F-16C aircraft.

Considering the magnitude of improved gun employment capability offered by EEGS, its cost is a windfall. The cost to modify each F-15 is broken down into a licensing fee for the General Electric Corporation (G.E.) and particular aircraft costs to the McDonnell Aircraft Corporation (MDC). The modification to F-15s involves a hardware change to the HUD processor as well as software changes. The programed cost for fully implementing EEGS on the F-15 fleet is only \$29 million; slightly more than the cost of one F-15 (4:--)! This amount is extremely reasonable considering the fact that one of the F-15's short-range missiles costs more than twice the amount to

required to retrofit one F-15 with EEGS. This figure is even more acceptable considering the F-15's increased killing capability using EEGS and the low cost of 20 mm ammunition. Recalling the scenario at the beginning of this paper where Capt. King's F-15 was lost due to the excessive time required to achieve a gun kill with the LCOS gun sight, it is very likely that the total program cost of EEGS can be saved in one aerial combat engagement.

Chapter Six

SUMMARY AND RECOMMENDATIONS

In today's air combat arena, a fighter's capability to kill quickly is a key ingredient in mission accomplishment and survivability. Its agility in the sky must be coupled with point-and-shoot weapon systems that either allow it to avoid the turning fight or quickly win it. Currently, the USAF's only air superiority fighter, the F-15 Eagle, does not have this quick-kill capability in short-range, visual engagements due to the severe accuracy limitations of its LCOS gunsight system. If an F-15 pilot decides or is forced to engage for a gun kill, the long maneuvering time required to attain gunshot parameters for the LCOS gunsight will most likely cost him his life.

In order to eliminate this short-range employment limitation and reestablish the F-15's combat effectiveness, TAC levied a formal requirement to develop an all-aspect gunsight system. EEGS is the result of this development. EEGS expands the gun envelope to all practical target aspect angles with or without a radar lock-on. It includes a means for accurate assessment of the simulated gunshots taken in daily exercises as an integral part of the sight.

Flight tests have demonstrated an expansion of more than 3-to-1 in the effective employment envelope of the gun with or without a lock-on in a manner that complements recent advances in missile technology. Time-to-kill, a key ingredient in aerial combat, was reduced over 65%. Imbedded training tools enable realistic, economical, daily training for maximizing combat readiness. EEGS combines the agility and advanced avionics of modern fighters with the unique skills of the trained pilot to provide a force multiplier effective in high threat environments characterized by dense ECM, IRCM, and threat fighters. EEGS essentially restores combat effectiveness in the F-15 for close-in or turning fights and eliminates defensive tactics required by the LCOS gunsight.

The unique capabilities of EEGS are already being incorporated in the

advanced F-16C and can be added to the F-15 fleet at a cost of approximately \$29 million; slightly more than the cost of one F-15. Without EEGS, F-15 pilots will remain unable to accurately achieve gun firing solutions on targets at aspect angles greater than 20-30 degrees. They will continue to favor defensive tactics and be unable to win close-in fights quickly. The result will undoubtedly be combat losses, each costing nearly \$29 million; the same cost for retrofitting the entire F-15 fleet with EEGS.

The TAF can not afford to allow its only air superiority fighter, the F-15 Eagle, to lack combat effectiveness in the short-range, visual combat arena. The F-15 was designed and developed to outperform and outfight any enemy fighter aircraft in the 20th century. This performance can not be realized unless the fire control system is updated with new technology and capabilities commensurate with the threat. Therefore, it is imperative that the F-15 air superiority fighter be retrofitted with the EEGS.

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