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EFFECT OF THE VISUAL IDENTIFICATION
REQUIREMENT ON EMPLOYMENT OF THE
F-15 IN THE NATO THEATRE

THESIS

AFIT/GST/OS/82M-12 Danny R. Rogers
Capt USAF

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The effectiveness of F-15 operation in the NATO environment is dependent on the employment rules of engagement (ROE). The necessity to visually identify an unknown prior to missile employment has neutralized the advantage of superior avionic and missile systems possessed by the F-15. F-15 effectiveness under two employment ROEs were evaluated: →

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2. BVR* employment: assumes the unknown to be hostile; therefore, provides for missile employment at the earliest opportunity.

The effect of the VID requirement on F-15 operation was evaluated through comparative analysis of VID versus BVR employment results generated by PACAM 8 simulation. The comparative analyses were based on mission-type and expected threat.

The VID effect upon F-15 operation against the enemy air-to-air threat was highly significant. The comparative factors were shot opportunities and shot sequencing. Against a vastly inferior threat, VID employment was an equalizing factor; whereas, against a similarly capable threat, the VID effect greatly reduced F-15 effectiveness.

The VID effect upon F-15 operation against the bomber threat was less pronounced. The F-15 effectiveness against low-altitude bombers is primarily dependent on missile reliability. Both BVR and VID employment doctrine provide adequate shot opportunities for effective F-15 employment.

The VID requirement places the F-15 in an environment where it is not only outnumbered (approximately 3 to 1 ratio), but where it must allow first shot opportunities to the enemy aircraft. Superior avionic and missile systems make the F-15 the premiere air superiority fighter in existence; however, the VID requirement reduces the F-15 to the equal of the Soviet first generation aircraft.

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EFFECT OF THE VISUAL IDENTIFICATION REQUIREMENT ON EMPLOYMENT OF THE F-15 IN THE NATO THEATRE

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Danny R. Rogers, B.S.

Capt USAF

Graduate Strategic and Tactical Sciences

March 1982

Preface

The evaluation of the effect of the visual identification requirement on F-15 effectiveness in the NATO theatre was predominately accomplished through simulation. This report provides the required background information to understand the problem and describes the process utilized to generate the final results.

During the evaluation process, a thorough knowledge of the PACAM 8 simulation model was required. Mr. Robert Mercier, Flight Dynamic Laboratory, Wright-Patterson AFB, was instrumental in providing the required knowledge necessary to effectively utilize the model in the evaluation process.

— Danny R. Rogers

Contents

List of Figures

Abstract

The effectiveness of F-15 operation in the NATO environment is dependent on the employment rules of engagement (ROE). The necessity to visually identify an unknown prior to missile employment has neutralized the advantage of superior avionic and missile systems possessed by the F-15. F-15 effectiveness under two employment ROEs were evaluated:

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EFFECT OF THE VISUAL IDENTIFICATION REQUIREMENT ON EMPLOYMENT OF THE F-15 IN THE NATO THEATRE

I. Introduction

Background

The evaluation of the expected effectiveness of any weapon system to be utilized in a specified conflict involves the following variables:

1. The weapon system's capability.
2. The threat to be encountered.
3. The rules of engagement (ROE) under which the weapon system is employed.

The F-15's utilization in the NATO environment will consist of bomber defense and counter-air employment. An additional role of "mini-AWACS" has been postulated depending on the overall effectiveness of AWACS command and control. In attempting to evaluate the effectiveness of the F-15 in the NATO battle scenario, each of the variables must be examined.

The F-15's overall capability as an air superiority fighter is very good. The F-15's strongest asset is in weapon employment capability. The F-15's radar, when combined with the radar missile (AIM-7), provides the F-15 a first strike capability against all known threat aircraft. The F-15's engines provide a thrust-to-weight differential which enables the aircraft to outmaneuver all known threat aircraft in the majority of the aircraft's flight envelope. The disadvantage the F-15 exhibits is in its survivability during close-in-conflict in a multi-threat environment. Maneuverability of the aircraft is not the critical factor. Rather, the aircraft's size and single-seat characteristics make it very easy to pick-up visually and provide enemy aircraft the advantage of maneuvering to stay in the F-15's blind areas during attacks.

This study focuses on the air-to-air threats only. These threats include enemy bomber and counter-air aircraft. The purpose of this study is to determine the relative capabilities of the F-15 against enemy bombers and counter-air aircraft under both Beyond-Visual-Range (BVR) missile employment doctrine and under the more stringent, Visual Identification (VID) required doctrine. These doctrines and their employment characteristics are discussed later in this chapter. The inclusion of surface-to-air (SAMS) and anti-aircraft (AAA) are not required to determine the F-15's relative capabilities since the threat from ground weapons can be considered constant for both employment doctrines. The air-to-air threat which will be encountered in a NATO conflict will provide the F-15 a target rich environment in which the F-15 has technological superiority.

Against the bomber threat, the F-15 has the maneuverability to intercept and the weaponry to employ air-to-air ordnance at any aspect angle to achieve bomber kills. The highest probability of kill (P_k) against bomber aircraft occurs during geometrical head-on employment. Head-on missile shots provide the AIM-7 its best capability while allowing the F-15 to remain clear of the bomber's defense systems. Employment of the AIM-7 under side or tail geometry reduces the overall effectiveness of the F-15 against bombers. In side attacks (beam area--90 degrees angle-off), the AIM-7 has limited capability due to the degraded ability of the missile to discriminate its target from ground signals. Employing the AIM-7 (or any weapon) in a tail attack places the F-15 in the threat envelope for bombers with tail guns.

Against enemy counter-air threat, the F-15 possesses first strike capability. First strike implies the ability to employ the first air-to-air missile in the engagement. The F-15 employed in pairs, will normally be outnumbered by the counter-air threat. The ability to launch the first missile in an engagement provides an equalizing effect to the numerical advantage the enemy possesses. The radar missile, once launched, will either strike its target or will be induced to miss by either system malfunction or enemy defensive reaction. The advantage in the first case is obvious--it reduces the size of the enemy formation.

In the latter case, the requirement for defensive reaction to defeat the missile will disrupt the preconceived plans the enemy formation was to employ to defeat the F-15s.

The obvious advantage the air-to-air threat possesses is in size. The NATO forces will be outnumbered by approximately a 3 to 1 ratio. Given equal capabilities, this would imply a tremendous advantage to the threat; however, the aircraft capabilities are not the same. A significant portion of the counter-air threat consists of clear-air-mass fighters which do not possess avionics capable of detecting and employing missiles against aircraft beyond-visual-range. These fighters do pose a significant problem to the F-15, but their overall effectiveness will depend on the size of the battle area and in their ability to receive guidance from ground-based radar sites, through radio communication, to the engagement areas. The later generation enemy counter-air aircraft do possess BVR capability. The USSR technology in avionics and missile development is inferior at this time to comparable US systems. The BVR capability available in the threat aircraft is inferior to that possessed by the F-15; however, the capability exists, and if used in a scenario where the F-15 is forced into a VID requirement, could provide first shot opportunity for the enemy.

Rules of engagement are normally imposed to structure the employment of weapon systems in the most effective manner consistent with the level of conflict encountered. The NATO force consists of a great variety of aircraft from different countries. This mixed-force employment concept has created numerous problems in the employment phase of operation. Along with such problems as aircraft performance, weapons, and tactics differences; differences exist in the identification systems (IFF) of each country's aircraft. This lack of "commonality" in the NATO force's IFF systems has created a visual identification (VID) requirement prior to air-to-air missile employment.

The VID requirement is necessitated by the inability of AWACS (Airborne Warning and Control System), GCI (Ground-based radars), or the F-15 to positively determine the identity of the unknown. The primary method of determining friend or foe is by interrogating the unknown's IFF and evaluating the response. The inability to achieve identification can be caused by any of the following:

1. Enemy jamming of electronics signals, thereby preventing the interrogation process;

2. The equipment possessed by the unknown is not compatible with the equipment being used to interrogate it;

3. The unknown's IFF is inoperative; or

4. The unknown is enemy, but does not provide an enemy response to interrogation.

The VID requirement dictates that the F-15 must visually acquire and identify the unknown as hostile prior to employing any weaponry. The geometry of the type intercept flown to accomplish a VID can vary from a head-on pass to a stern conversion. F-15s working in pairs have two distinct options in order to employ air-to-air missiles as soon as possible. The options are:

1. In the head-on pass, the F-15s are required to split-up into a lead-trail formation. The lead F-15 identifies the target as hostile and clears the trailing F-15 to fire his radar missile.

2. The second option is for the F-15s to split and bracket the enemy formation. This involves attaining lateral separation (each F-15 lagging to opposite sides of the enemy formation) to provide turning area for completion of the intercept into identification range.

In both options, the F-15s are placed well within the range of the enemy's radar missile capability. Efforts have been made to increase the visual identification range by use of enhanced-optical systems (i.e., the F-15 has Eagle Eye, F-4 has Tiseo). However, even with identifications out to maximum limits of these systems, the F-15 is still vulnerable to threat missiles prior to employment of their own missiles.

Beyond visual range employment doctrine allows for weapon employment outside of visual range without electronic identification. Analysis of the unknown's flight parameters (geographic position, heading, altitude and spe d) can be used as identification factors in declaring the unknown as friend or foe.

Problem Statement

The lack of an adequate IFF system to be utilized by the combined NATO air-to-air forces has created the requirement for visual identification of unknowns prior to radar missile employment by NATO intercept aircraft. Variety and unreliability of the present IFF systems used by NATO forces cause electronic identification to be less than adequate. In order to minimize the number of friendly aircraft inadvertently engaged by air-to-air missiles, the VID was instituted as a prerequisite to missile employment against unknown aircraft.

The VID requirement affects the capability of the different NATO interceptor aircraft to different degrees. The major thrust of this report is to investigate the effect of VID requirement upon the capability of the F-15 to perform its air-to-air doctrine in the NATO environment. This involves evaluation of the F-15's performance in bomber defense and counter-air roles under both VID and BVR rules of engagement.

The problem is not to determine if the VID requirement inhibits maximum employment of the F-15, but rather to determine to what extent the VID requirement inhibits

F-15 effectiveness. A follow-on issue is: Can the NATO force accept that degree of reduction in capability.

Statement of Objectives

1. Establish base-line F-15 employment effectiveness in the NATO environment under BVR rules.

2. Determine the reduction of F-15 employment effectiveness in the NATO environment given the VID requirement through the following process:

a. Through the use of computer simulation, determine the optimum expected F-15 effectiveness against the counter-air/bomber threat under both VID required and BVR allowed rules of engagement.

b. Through comparative analysis of each engagement (BVR versus VID), identify the critical factors affecting F-15 employment effectiveness.

c. Through analysis of the critical factors, determine the expected loss of effectiveness by the F-15 in the NATO environment.

Methodology

The evaluation of the F-15's capability against the threat will be accomplished through computer simulation. The model to be utilized is PACAM 8. PACAM 8 is the latest version of the PACAM series. The use of PACAM is controlled by the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico. The model simulates the performance of aircraft and weapons in combat. PACAM 8 provides the capability to evaluate engagements with up to four aircraft per side (4 versus 4). Through the input of aircraft performance data, weapons capability, and air-to-air maneuver priorities: the model simulates the specified engagement and provides the probability of survival, P_s, of each aircraft.

The F-15's primary role in a NATO conflict will be bomber defense. This involves the detection, identification, and weapons employment against high-speed, low-altitude, threat aircraft. In simulating the threat bomber aircraft, the formation size and speed of the penetrating bombers will be varied in order to accurately represent current enemy tactics and capabilities. Due to the limited reaction capability in the bomber threat, speed and number-in-formation variations suffice as control variables in determination of the F-15's effectiveness against them.

The specific scenarios will depict the F-15s, employing in pairs, engaging bomber forces varying in size from 2 to 4 aircraft (four aircraft formations provide sufficient threat aircraft to evaluate optimum F-15 effectiveness). Simulations will be made to determine the expected effectiveness of the F-15s against the enemy bombers under both VID and BVR conditions. From comparative analysis of these results, the reduction in F-15 bomber defense effectiveness due to the VID requirement can be established.

Although the primary role of the F-15 is postulated as bomber defense, the role of air superiority is just as viable. Air Superiority implies control of a specific air space (i.e., the ability to implement air operations without major interference from enemy air-to-air threats). The F-15s will be employed in pairs against threat formations varying in size from 2 to 4 aircraft. Four aircraft formations simulate the numeric advantage of the threat and also allows for employment under enemy tactical doctrine. The required inputs (aircraft capabilities, missile capabilities, and maneuver priorities) will depict current F-15 and enemy capabilities/tactics. The specific scenario results will depict the F-15's effectiveness against a particular threat aircraft under both VID and BVR conditions.

II. The Model

PACAM 8 (Piloted Air Combat Analysis Model) is a computer model, written in FORTRAN IV code, designed to simulate air-to-air combat to assist in the evaluation of aircrafts, armaments, and tactics. Still in final development stage, PACAM 8 has evolved through modifications to PACAM I, which was originally designed in 1968 by direction of the Aeronautical Systems Division/Research Laboratory. The following chronological listing represents the major modifications which have preceded the current PACAM capability:

PACAM I. Established the capability to simulate one versus one, three-dimensional aerial combat. Flexibility of the model was severely degraded due to the limitations in tactics and maneuvers which could be incorporated. In addition, there was no missile employment capability within the model.

PACAM II. The model incorporated the use of assymetric tactics by the opposing aircraft and the employment of air-to-air missiles. Assymetric tactics provided each side the capability to evaluate the combat situation and select the most appropriate tactic. Missile employment was incorporated; however, individual aircraft reactions to missiles employed, were not incorporated.

PACAM IV. (no PACAM III) Increased the simulation capability of the model to a maximum of four aircraft. Integrated defensive reaction to missile employment into the tactics selection process of the targeted aircraft. Introduced bomber tactics to provide for evaluation of penetration capability of bombers.

PACAM V. Introduced surface-to-air missile integration into the threat evaluation process to determine aircraft tactics.

PACAM 8. (no PACAM VI or VII) Increased the capability of engagement simulation to eight aircraft. Introduced weapon employment coordination among all aircraft on the same side to ensure adequate weapon dispersal against the opposing side.

Figure 1 depicts the flow of data within the model. The flow of information within PACAM 8 is driven by the physical simulation cycle. The physical simulation cycle tracks the movement of vehicles (aircraft and missiles) within the engagement. As the figure depicts, the actual movement process is evaluated every .025 second. The weapon decision cycle (choice of weapon) is updated with the effects of movement within the engagement every .1 second. Similarly, every second, the new input data

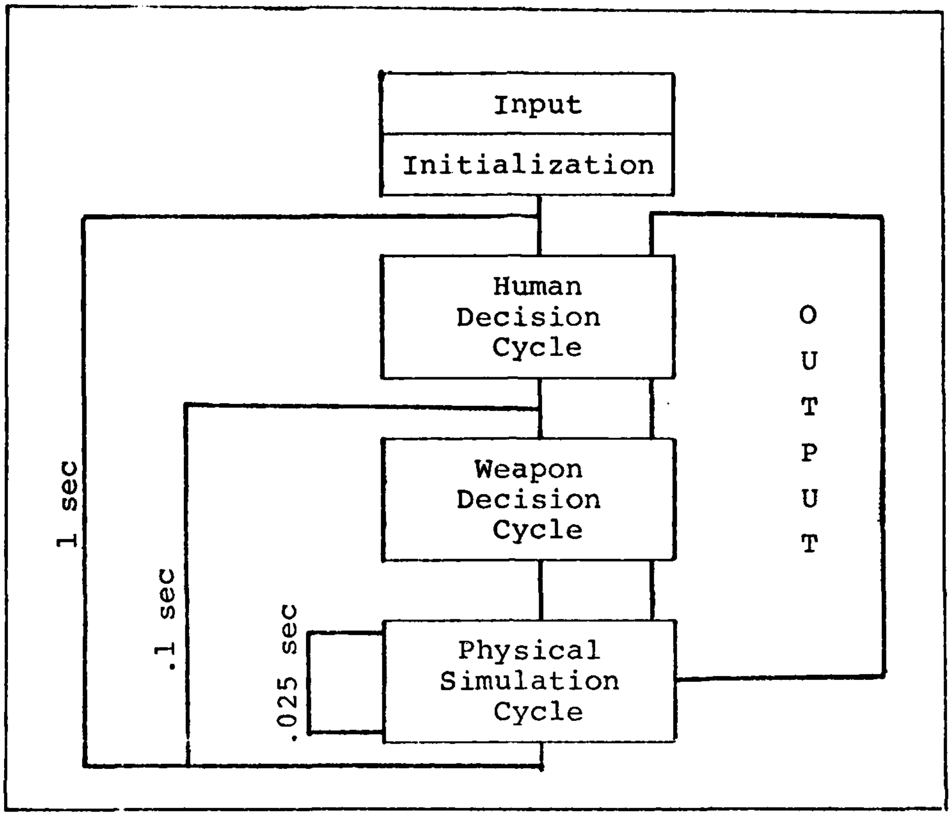

Fig. 1. Data Flow Within PACAM 8

obtained from movement within the engagement is provided to the human decision process.

To provide understanding of both the operation of the model and the flexibility of the model, each function is examined.

Input

There are nine basic input categories which provide PACAM 8 its full capability. The variety of inputs provides enormous flexibility in creating realistic scenarios for potential hostile areas. In creating the

NATO environment, only seven of the nine input categories were utilized. Surface-to-air missile and laser inputs were not used.

1. Control and Scenario Parameters. These parameters provide the required descriptive data to exercise the model. These parameters include:

a. Number of aircraft on each side. PACAM 8 can evaluate up to eight aircraft total. Variations in the number of aircraft on each side provide the capability to simulate engagements of one versus one through engagements of four versus four.

b. Tactics. The available tactics set provides the capability to simulate the current tactical doctrine of each respective adversary. The set includes single-fighter tactics, double-attack tactics, free and engaged tactics, welded-wing tactics, integrated-attack tactics, and bomber penetration tactics.

(1) Single-fighter tactics. The aircraft maneuvers against and attacks the most advantageous enemy aircraft. No coordination is accomplished to ensure the target is not being engaged by another friendly aircraft.

(2) Double-attack tactics (2 aircraft). Each aircraft initiates separate attacks against the enemy formation. Coordination is accomplished, within the two-ship, to ensure dual attacks against the same target do not occur.

(3) Free and engaged tactics (2 aircraft). The lead aircraft in the formation employs as if a single fighter. The free aircraft maneuvers relative to the engaged aircraft to establish the position required to enter the fight should the engaged aircraft fail to kill the target.

(4) Welded-wing tactics (2 aircraft). The lead aircraft employs as a single fighter while the wingman maintains a particular support position. Both aircraft can employ weapons; however, the maneuvering of the flight is determined by the tactics employed by the lead aircraft.

(5) Integrated-attack tactics (4 aircraft). Provides interaction between the aircraft in each formation relative to target selection and attack options. This provides equitable distribution of weapons employment by the formation against each aircraft in the opposing formation.

(6) Bomber penetration tactics (2 aircraft). Establishes the bombers' flight path to the ground target and provides for defensive reaction in the event of interception by the air-to-air threat. The lead bomber determines the maneuvers to be initiated. The maneuvers are designed to place the attacking aircraft within the bombers' defensive weapon envelope.

c. Duration of engagement. Provides one method of terminating the engagement. For example, in simulating the NATO environment for engagements against the counter-air threat, 150 seconds of combat time was utilized as the terminating factor.

2. Aircraft Type Inputs. PACAM VIII can evaluate two different aircraft types per engagement. Each aircraft type is defined through:

a. Aerodynamics of the aircraft

b. Engine(s) of the aircraft

c. Structural limits of the aircraft

d. Weaponry of the aircraft

e. Pilot limitations withi the aircraft

3. Missile Type Inputs. PACAM 8 can evaluate both air-to-air and surface-to-air missiles. Each missile type is defined through aerodynamic, structural, and motor characteristics. In addition, the lethal radius of the warhead of each missile type is incorporated for use in determination of kill probabilities associated with target miss distances.

4. Firing Screen Inputs. These inputs define the conditions which must exist between the attacker and the target prior to weapon employment. For example, to employ the radar missile the attacker must have the weapon on board the aircraft, be radar tracking the target, and be within the maximum and minimum ranges of the missile.

5. Detection Contours Inputs. These inputs provide for variability in the respective aircraft's radar

detection range to accommodate for both changes in aspect angle of the target and the use of electronic deception by the target.

6. Tactical Inputs. The tactical inputs dictate the maneuver which each aircraft in the engagement performs at each specific time interval. The selection of the maneuver is dependent upon each aircraft's posture, priority list, and decision matrix.

a. Posture. An aircraft's posture is its perceived combat relationship against a single opponent. For fighter aircraft, there are six postures: Attack, Convert, Defense-Zone 1; Defense-Zone 2; Defense-Zone 3; and Defense-Zone 4. It is highly probable for each aircraft to have several postures at the same time during the engagement. This occurs since the aircraft's position is evaluated against all opposing aircrafts/missiles within the engagement.

b. Priority list. A priority list is provided for each aircraft to determine the posture to be utilized in the maneuver selection process. Variations in an aircraft's priority list enables evaluation of aggressive tactics versus defensive tactics. Figures 2 and 3 illustrate graphically the posture delineation process and Figure 4 provides a sample priority list. From the perspective of the threat aircraft, Figure 3 represents the instantaneous partitioning of the F-15s into perceived postures.

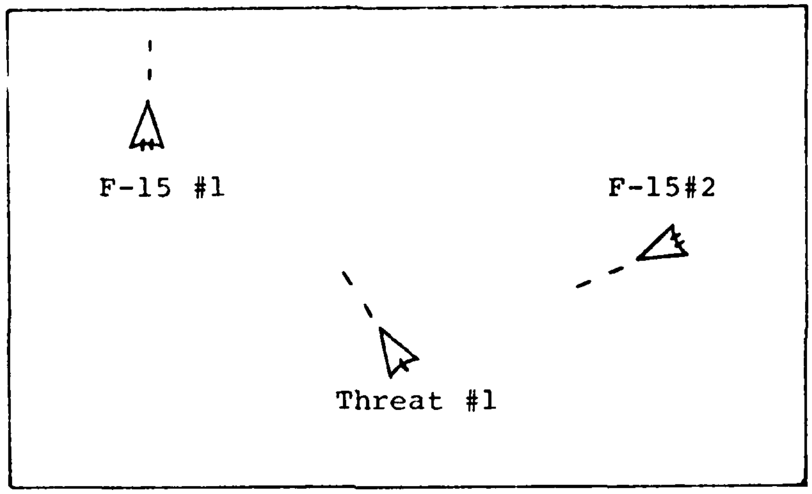

Fig. 2. Aircraft Posture Delineation Process: Aerial Geometry

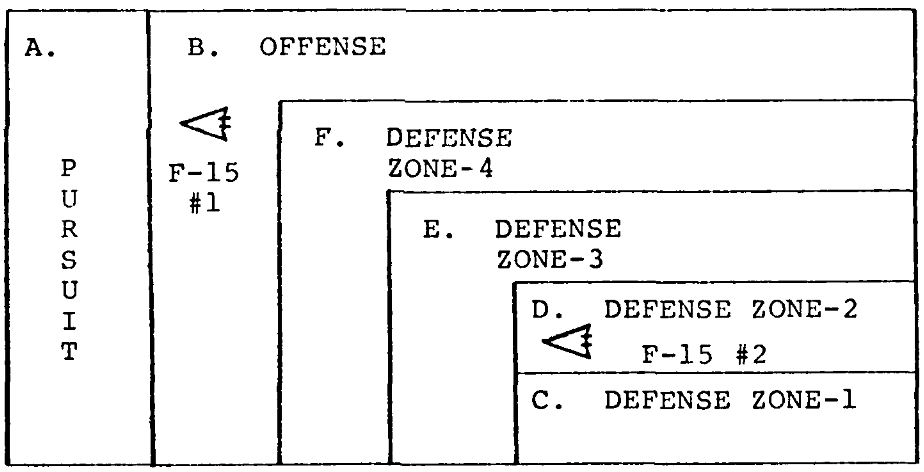

Fig. 3. Aircraft Posture Delineation Process: Partitioning of Threats

REGION	PRIORITY
A	4
B	3
C	1
D	2
E	5
F	6

Fig. 4. Aircraft Posture Delineation Process: Priority List

Referring to Figure 3, C, D, E, and F areas represent the threat's defensive zones 1-4, respectively. Each defensive zone is defined through angle and distance from the tail of the threat aircraft. Area A represents the attack zone and area B the convert zone. The model evaluates the position of opposing aircraft and assigns postures as applicable. In the illustration, threat #1 has two postures: B and D. To explain: in the aerial view, threat #1 has F-15 #1 in front of him; therefore, threat #1 is offensive with respect to F-15 #1. Conversely, threat #1 has F-15 #2 in his rear hemisphere; therefore, threat #1 has a defensive posture with respect to F-15 #2. To determine which posture to utilize in the evaluation of the threat's next maneuver, the Priority List is used (Figure 4). In the illustration, D has the highest priority (lower number is higher priority); therefore, D posture is used as the threat's posture in the maneuver selection process.

c. Decision matrix. Once the posture of the aircraft is determined, the maneuver is selected by a decision table/matrix. For single aircraft, the maneuver is a direct function of the aircraft's posture. For aircraft working in pairs, the following maneuver selection process applied:

(1) For free and engaged tactics, the engaged aircraft's maneuver is determined through its single-ship maneuver table. The free aircraft's maneuver is a function of both the free and engaged aircrafts' postures as defined through the pair's maneuver decision matrix.

(2) For double-attack tactics, both aircrafts' maneuvers are dictated by their joint posture maneuver decision table.

Figures 5, 6, and 7 depict the three types of decision processes. Figure 8 depicts the list of available maneuvers.

7. Initial Conditions Input. Utilizing two subprograms, the aircraft and weapons to be employed in the simulation are defined. Each aircraft (up to a maximum of eight) is defined through the following inputs:

a. Friend or enemy

b. Lead or wingman

	POSTURE	MANEUVER
A. ATTACK		
PURSUIT	A	1
B. CONVERT		
CONVERT	B	2
C. DZ-1		
JINK	C	3
D. DZ-2		
HARD TURN	D	4
E. DZ-3		
ESCAPE,LO	E	5
F. DZ-4		
ESCAPE,HI	F	6

Fig. 5. Maneuver Selection Process: Single Fighter

FREE-ENGAGED MANEUVERS MATRIX

Priority				Free Fighter A	B	C	D	E	F
A	2		A	9	9	9	9	9	9
B	4		B	9	9	9	9	9	9
C	1	ENGAGED	C	1	2	2	2	2	2
D	3	FIGHTER	D	1	2	2	2	2	2
E	5		E	1	2	3	4	5	2
F	6		F	1	2	3	4	5	6

Fig. 6. Maneuver Selection Process: 2 Fighters, Free and Engaged Tactics

DOUBLE ATTACK MANEUVERS MATRIX

		Wingman A	B	C	D	E	F
LEAD FIGHTER	A	1-9	1-9	1-3	1-2	1- 9	1- 9
	B	9-1	2-9	2-3	2-2	2-16	2- 9
	C	3-1	3-2	3-3	3-4	3-15	3-15
	D	2-1	2-2	4-3	2-9	2- 2	4- 6
	E	9-1	16-2	15-3	2-2	2- 9	2- 6
	F	9-1	9-2	15- 3	6-4	6- 5	6- 6

(first number represents lead aircraft's maneuver; second--wingman's)

Fig. 7. Maneuver Selection Process: 2 Fighters, Double Attack Tactics

Code	Maneuver
1	Lead pursuit for gun firing
2	Offensive turn to get to pursuit course
3	Defensive jink
4	Defensive turn
5	Escape, low
6	Escape, high
7	Continue unaware
8	Fly formation with partner
9	Attempt to bracket opponent
10	Out of combat due to being shot down
11	Evade missile
12	Disengage due to bingo fuel
13	Disengage
14	Chandelle
15	Split-S
16	Immelman
17	High speed yo-yo
18	Barrel roll
19	Bomber penetration
20	Bomber defensive action

Fig. 8. Maneuver Selection Process: List of Available Maneuvers

c. Initial starting flight parameters (altitude, airspeed, and initial position within the engagement scenario)

d. Weapon load (type and number of missiles/gun)

Human Decision Cycle

Through the integration of seven subprograms, this process determines the flow of the engagement. The human decision process involves aircraft maneuver and weapon employment selections.

1. Aircraft Maneuvering. Through three subprograms: the aircraft's posture is determined; the maneuver is selected; and a review is accomplished to ensure the chosen maneuver is feasible for the current flight parameters (altitude and airspeed).

2. Weapon Employment. Through four subprograms: all feasible targets are identified; a specific target is selected; all weaponry is evaluated; and the weapon to be employed is selected.

Weapon Decision Cycle

Through the integration of five subprograms: the weapon to be employed is chosen; the performance of the weapon inflight is monitored; and the results of weapon employment are evaluated. In addition, the weapons remaining on the aircraft and the fuel status of the aircraft are evaluated to determine its combat capability.

Physical Simulation Cycle

The actual movement of both aircraft and missile, within the simulation, is accomplished through the six subprograms within this cycle. The effects of aircraft/missile movement are evaluated and the new flight parameters (i.e., velocity, altitude, and weight) are computed and routed to the Human/Weapon Decision processes for utilization during the next decision cycle.

Output

Numerous output options are available in PACAM 8. To investigate the effects of the visual identification requirement on the effectiveness of the F-15, the outputs utilized were:

1. Standard Aircraft Report. This output provides flight parameters (altitude, airspeed, gees, etc.) of each aircraft at each time pulse. This provides the capability to monitor each aircraft's tactic and allows for manual recreation of the engagement to determine the critical areas.

2. Narrative Output. Provides a chronological listing of all major events during the engagement. The major events include weapon employment, aircraft's reaction to either enemy aircraft or missile, and provides missile/

gun results. This output aids in the tracking of missile employment and also provides cumulative survival probability of each aircraft.

Model Limitations

PACAM 8 adaptability to a NATO environment is good. However, certain assumptions/limitations incorporated within the model do limit the realism of the engagement simulation.

1. Two aircraft types per engagement. To more completely investigate the F-15's effectiveness against the Warsaw Pact threat, the simulation of mixed aircraft employment should be accomplished. This involves both the simulation of F-15s versus mixed enemy formations and the simulation of NATO, mixed force employment against the threat aircraft.

2. Homogeneous aircraft capabilities. Within each formation, all information is known to each aircraft. This assumes that all systems (communication, avionic, and IFF) operate at equal effectiveness levels for each aircraft within the formation. This assumption provides for evaluation of employment at various levels of system operation; however, it does not allow for evaluation of mixed capabilities within the formation.

3. Information is perfect. The information obtained by any adversary is perfect information. This

prohibits the introduction of human error in threat assessment into the engagement simulation. The entire flow of the engagement will be tactically correct as dictated by the particular tactical logic given to each adversary. The effects of indecision, stress, fear, and error in the operation of each adversary can not be investigated.

III. Simulation

The simulation process to determine the relative effectiveness of F-15 employment in the NATO environment under the VID required and BVR allowed rules of engagement consists of the following scenarios:

1. Evaluation of F-15 effectiveness against the Type 1 and Type 3 counter-air threats.

2. Evaluation of F-15 effectiveness against low-altitude bomber penetrators with variance in penetration airspeed capability.

Counter-air Threat Scenario

The F-15s are employed in pairs against enemy counter-air threat formations varying in size from two to four aircraft. The F-15s are flown at medium altitude (10,000 feet) with the threat aircraft positioned slightly higher (20,000 feet). The air-to-air engagement is initialized outside of F-15 maximum radar missile employment range, with the two formations flying head-on intercept headings. Specific aircraft performance capability is provided to each participant, along with the maximum load of missiles and gun ammunition allowed. Figure 9 indicates the scenarios evaluated.

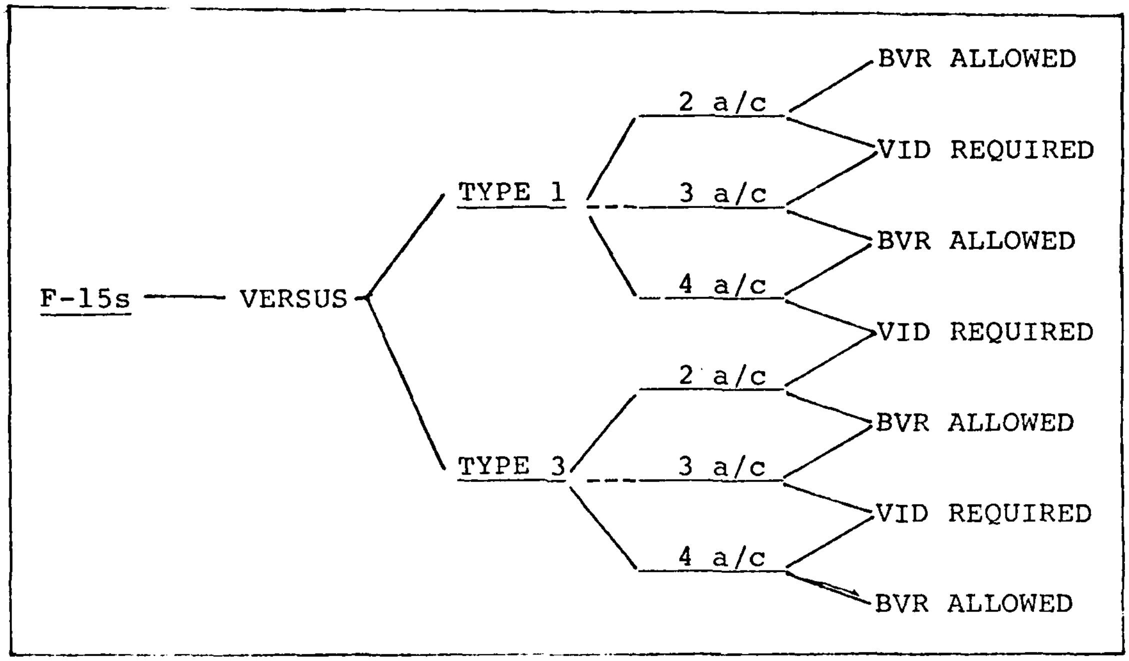

Fig. 9. F-15 Versus Counter-Air Threat Scenarios

The evaluation consists of 12 simulations, each representing 150 seconds of combat time. There is no kill removal from the simulation (i.e., all aircraft continue to function according to maneuver priority established regardless of missile results); however, the cumulative probability of survival is updated for each aircraft after a weapon employment event.

Justification

The following represents justification for the inputs and structure of the counter-air simulations:

1. The counter-air threat consists of first through fourth generation Soviet aircraft. To simulate

each specific counter-air threat aircraft versus the F-15 would be too costly; therefore, threat aircraft have been grouped into two distinct categories:

a. The Type 1 threat aircraft represents the threat with less avionic, missile, and performance capability than the F-15. The capabilities defined for the Type 1 threat represent a compromise of Soviet first and second generation aircraft capabilities versus the F-15.

b. The Type 3 threat aircraft represents the threat with similar avionic and missile capability, but less performance capability than the F-15. Type 3 aircraft capabilities reflect a compromise of Soviet third and fourth generation aircraft capabilities.

Figure 10 depicts the capabilities provided each aircraft evaluated.

AIRCRAFT	MAX AIRSPEED	MAX GEE	RADAR (0° ASPECT)	MISSILES
F-15	MACH 1.2 @ Sea level MACH 1.7 @ 20,000 feet	9.33	Detection: 24 NM Track: 24 NM	4 x Radar 4 x Heat
Type 1	MACH 1.0 @ Sea level MACH 1.3 @ 20,000 feet	7.0	Detection: 8 NM Track: 5 NM	4 x Radar 2 x Heat
Type 3	MACH 1.1 @ Sea level MACH 1.7 @ 20,000 feet	7.0	Detection: 24 NM Track: 16 NM	4 x Radar 4 x Heat

Fig. 10. Comparison Chart: F-15 Versus Counter-Air Threat

2. The employment of the F-15s in pairs is consistent with current training doctrine.

3. The tactics sets assigned to the adversaries (double-attack to the F-15s and welded-wing to the threat) simulate respective employment doctrines.

4. The F-15 employment altitude was chosen to maximize its radar capability in detecting enemy bomber penetrators. The engagements against the counter-air threat will primarily be by necessity, rather than by design; therefore, the F-15s' employment altitude reflects their primary mission-bomber defense.

5. The variations in enemy formation sizes reflect basic Soviet tactics and simulates the numeric advantage possessed by the Warsaw Pact forces over the NATO forces.

Bomber Threat Scenario

The F-15s are employed in pairs against enemy bomber formations varying in size from two to four aircraft. The F-15s are flown at medium altitude (10,000 feet) with the bombers positioned at low-altitude penetration altitude (200 feet). The bombers' defensive reactions consist of aircraft maneuvering and increasing/decreasing airspeed. The engagement is initialized outside of F-15 maximum radar missile employment range. Figure 11 depicts the scenarios evaluated.

Justification

The following represents justification for the inputs and structure of the bomber simulation:

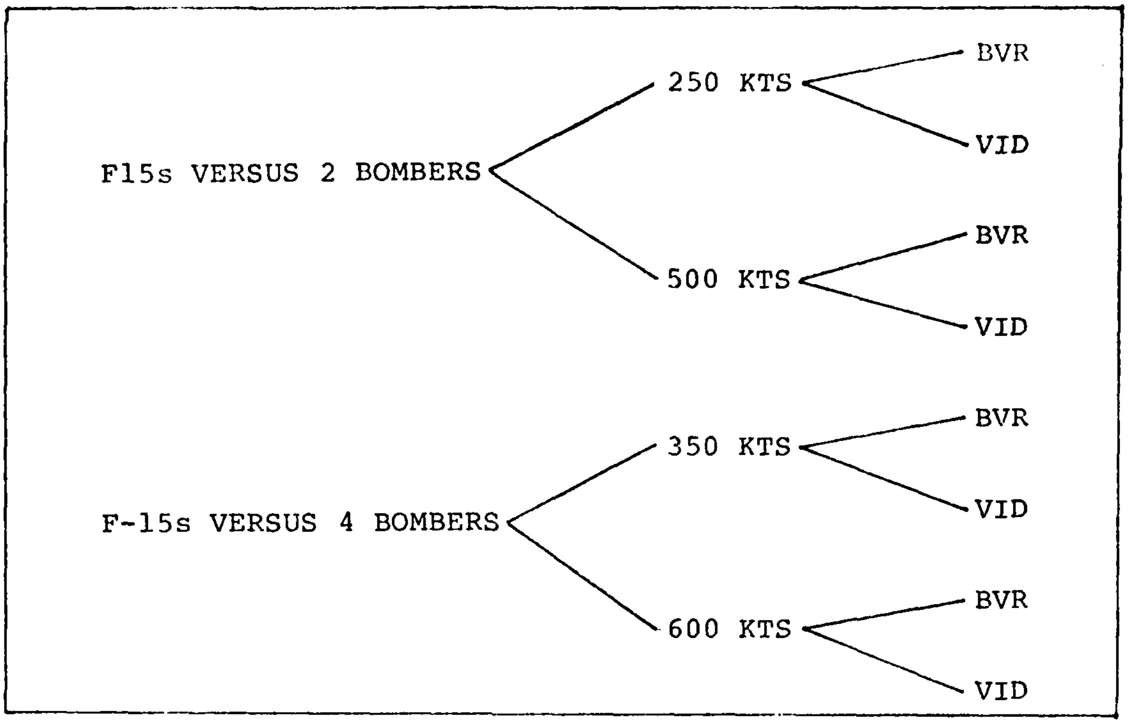

Fig. 11. F-15 Versus Bomber Threat Scenario

1. The Warsaw Pact bomber force consists of numerous types of aircraft with a wide range of capabilities. To evaluate the F-15's effectiveness against each particular bomber type would be too costly. The concern of this study is the F-15's effectiveness against the low-altitude penetrators. Low-altitude penetrators are by necessity highly maneuverable. The variable capability among the Soviet low-altitude bombers is penetration airspeed. To investigate the effect of the VID constraint on bomber defense, the penetration airspeed of the bombers is varied between 350 and 600 knots.

2. The bombers' penetration altitude was set at 200 feet (lowest PACAM 8 capability).

3. The bombers' formation size was limited to a maximum of 4 aircraft. Four threat bombers provide sufficient threat aircraft to evaluate the optimum F-15 effectiveness.

4. The F-15 employment altitude was chosen to maximize its radar capability in detecting enemy bomber penetrators. The mountainous terrain encountered requires a medium altitude for the F-15 to ensure continuous line-of-sight illumination of low-altitude targets.

IV. Analysis of the Simulation Process

To utilize any data generated through simulation, it is necessary to understand how the data was generated; the applicability of the data to the evaluation; and the constraints concerning use of the data. To justify the use of the data obtained from the simulation of the NATO environment to investigate F-15 effectiveness, the following analyses are provided:

1. The function of the model
2. The variables within the model
3. The verification of the model
4. A comparison flowchart

Function of the Model

As described in Chapter II, PACAM 8 is a highly sophisticated model capable of simulating air-to-air engagements and providing various outputs dependent upon the capabilities provided to the participants within the simulation. The level of realism that can be achieved through any simulation process depends on the number of variables which can not be adequately integrated into the simulation.

In the determination of the flow of the engagement, PACAM 8 utilizes specific capabilities of each adv -sary to provide the relevant data for selection of maneuvers to be accomplished. The process involves the selection of the maneuver from the designated tactics set for each adversary. There is no indecision at the maneuver selection level. The maneuver selection depends upon data received as a function of the adversary's capability, the correlation of the data to the respective tactics set, and the aircraft's maneuver capability. The influence of the following capabilities can <u>not</u> be simulated: the human error factor; the effects of stress and fear; and the spectrum of flying abilities within each adversary's force. The result of these limiting factors is that the data generated represents the effects of perfect information, maneuver selection, and performance; consistent with each adversary's defined capability and tactics doctrine.

Knowledge of the type data generated provides the capability to properly incorporate the data into the analysis process. Since the data generated represents perfect execution, consistent with each respective adversary's capability, the comparison of F-15 effectiveness will be accomplished at this level of execution capability.

Since individual reactions under various degrees of stress/fear and the probability of human error in situation evaluation/maneuver performance can not be realistically modeled, the comparison of perfect performance provides the most useful data in evaluating the change in effectiveness of the F-15 under both changes in rules of engagement (ROE) and changes in enemy formation size/ capability. Assuming the actual performance capability for aerial combat execution by each adversary to be proportional to the upper limit of capability demonstrated by the model enables use of output data from the model to indicate increase/decrease in effectiveness under different scenarios. This study involves a comparison of effectiveness; therefore, the relative changes determined by simulation to result from ROE employment/threat size/ threat capability differences reflect the actual increase/ decrease of performance effectiveness during actual execution.

The following statements suggest that the actual execution capability for both the F-15 and the threat are reasonably proportional to the perfect execution capability predicted by the PACAM model:

1. The F-15's actual execution capability within a NATO-type environment is evaluated during large, combined-force exercises continuously. The realism involved in these exercises projects stressful situations where decisions must be made and provides for thorough post-flight analysis of these decisions to aid in the training process. The training accomplished should provide adequate preparation for adjustment to less than

perfect information and provide for efficient utilization of the F-15.

2. The enemy's employment doctrine is very structured. Flight maneuvering is predominantly directed by ground controllers to eliminate errors by pilots during stress situations.

This assumption allows direct use of the model's capability to evaluate, at each time pulse, each participant's ability to employ offensive weaponry against the respective adversary. Within the counter-air scenarios, this method involves a direct correlation of missile employment opportunities to the overall effectiveness of the respective opponents. Missile opportunities are dependent upon the specific engagement scenario. For example, the F-15s employed (BVR allowed) against the Type 1 threat have missile opportunities prior to the threat aircraft employing weaponry. The resulting defensive reactions by the targeted aircraft deny missile employment opportunities by these aircraft during the defensive maneuvers. Against the same threat however, VID employment provides the threat aircraft the first shot advantage. The F-15s are denied missile employment while defending against the threat's missiles. Therefore, in the comparative analysis of the counter-air engagements (BVR versus VID), the number of missile opportunities, not the missile results, were used.

Within the bomber scenarios, the comparative analysis reflects missile effectiveness versus the type of missile employed. Due to the limited reaction capability of the bombers, the P_k of each missile represents specific capabilities provided each adversary.

Variables Within the Model

The data generated by the simulation represents changes in the flow of the engagement due to either ROE considerations or the formation size of the enemy force. The effects of changes in these two variables are evaluated for the two different enemy aircraft types for F-15 counter-air missions and by variations in bomber penetration airspeed for the bomber defense missions.

The selection of the two primary missions to be evaluated was covered in Chapter I. To review, the primary mission of the F-15 is to utilize its advanced weapon technology to intercept and destroy enemy bombers. The necessity of employing against the counter-air threat is due to the Soviet integrated attack operations which provide simultaneous air-to-air threat employment to enhance their bomber penetration capability. Thus the F-15s must face counter-air threats in order to intercept and destroy enemy bombers.

The grouping of the Warsaw Pact aircraft into threat types was necessary to limit the scope of this evaluation. The data provided to simulate the two counter-air threat types represent an effort to group the threats by technological and performance characteristics. The threat's bomber capability is simulated by variance of bomber penetration airspeed.

The variation in enemy formation size depicts the threat's numeric advantage consistent with Soviet employment doctrine.

The selection of each adversary's employment doctrine (F-15s' use of double-attack and the enemy's use of welded-wing) conforms to the ideology of air-to-air employment of the respective adversary. Limitations within PACAM 8 prohibited the evaluation of mixed-force employment which would have added to the realism of the study.

The actual variable utilized in this study to evaluate the relative F-15 effectiveness is employment ROE. All other variables are used as the comparative standards. All results represent analysis of the employment differences concerning BVR versus VID rules of engagement. This method provides the opportunity to investigate different levels of changes in effectiveness due to the different enemy aircraft type, formation size, and mission.

Verification of the Model

PACAM validation in the area of maneuver execution was accomplished previously by utilizing comparative analysis between actual engagement scenarios flown and the graphic representation received through simulation. A review of the validation process is contained in the PACAM V Analyst's Manual. The final product, after modifications, represents the best capability to simulate aerial combat available.

Assuming that the maneuvers are representative of the capabilities provided each participant, verification of the model investigates changes in simulation output resulting from changes in data input. The following represents relative effects on the flow of the engagement by variance of the defined variable to reflect realistic execution of the scenarios:

1. Counter-air scenarios.

a. Enemy aircraft capability. An increase in weapon/avionic technological capability should result in an increase in overall missile employment opportunities by the threat aircraft within the simulation. For example:

(1) A Type 3 threat aircraft versus the F-15 should reflect more shot opportunities than a Type 1 threat aircraft (all other factors constant).

(2) F-15 employment under BVR rules of engagement should reflect more shot opportunities than employment under VID rules of engagement against a particular threat.

b. Number of aircraft in threat formation. Increasing the threat formation size provides:

(1) More missiles to be employed by the threat.

(2) At least one threat aircraft that is not targeted by the F-15s at the same time.

(3) More targets for the F-15s to employ against.

Analysis of the effects of changes in formation size is not as simple as it appears. Due to the maneuver constraints of the threat (welded-wing), the three-ship and four-ship formations react to threats in a similar manner. Depending on the specific time pulse being evaluated, the four-ship could have increased missile employment opportunities or could be providing more targets for F-15 missile employment.

2. Bomber scenarios.

a. Rules of engagement variation from BVR to VID could decrease the efficiency of the F-15. The requirement to VID will inhibit the employment of missiles until the F-15 are within visual acquisition range of the targets. However, the loss in BVR missile P_k could be negated by variance in the missile selection sequence. For example, the more reliable short-range, heat-seeking missile could dominate the missile employment sequence during VID employm nt, while the long-range radar missile is prevalent in the BVR employment missile sequence.

b. An increase in bomber penetration airspeed should decrease F-15 effectiveness. The decrease in effectiveness is due to a decrease in shot opportunities in the more reliable head-on geometry employment.

Comparison Flowchart

1. Counter-air Scenario.

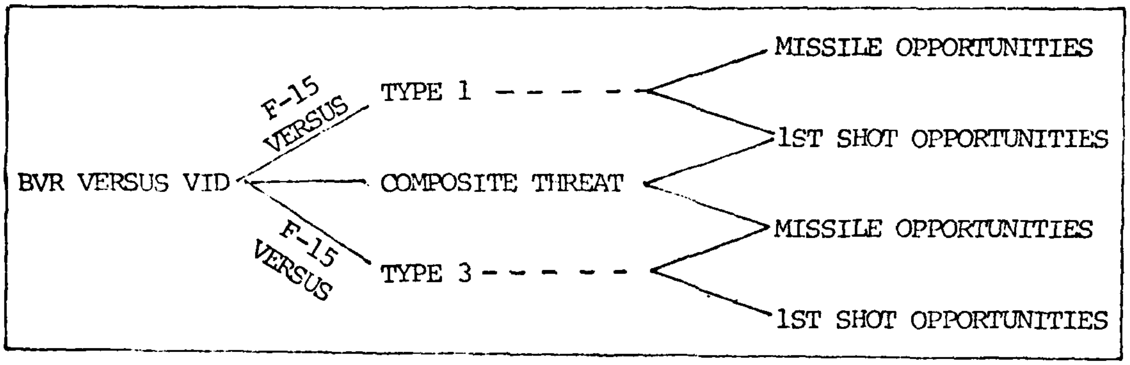

Fig. 12. Counter-Air Threat: Comparative Factors

2. Bomber Penetration Scenario.

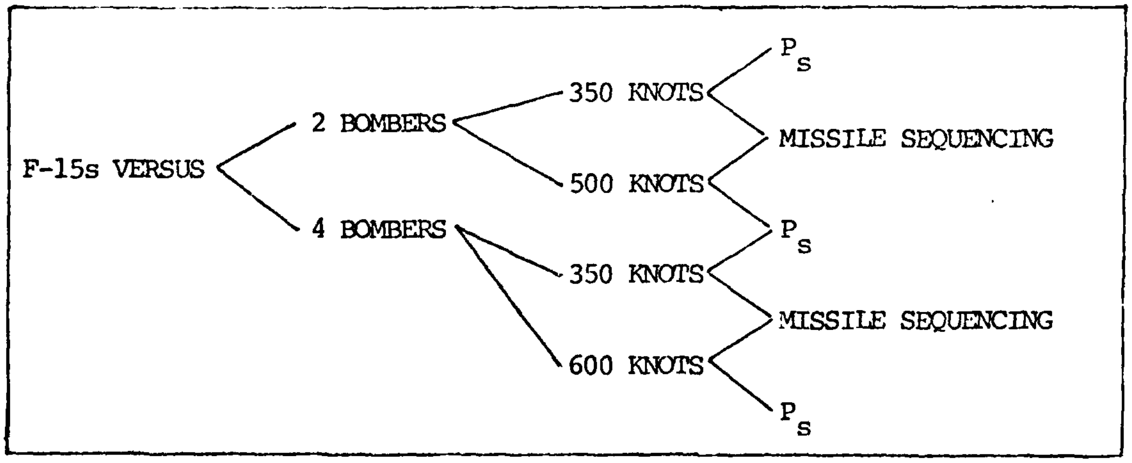

Fig. 13. Bomber Threat: Comparative Factors

V. Comparative Analysis

The comparative analysis is broken down into two sections. The first section analyzes the effects of the VID constraint upon F-15 effectiveness against the counter-air threat in the NATO environment. The second section analyzes the effects of the VID constraint upon the F-15 effectiveness against the bomber threat in the NATO environment. In the analysis process, each engagement type is investigated to identify the critical factors within the engagement.

Counter-air Threat

All of the counter-air threat simulations were terminated at the conclusion of 150 seconds of simulated combat time.

1. Type 1 Threat Aircraft (2 versus 2).

a. Critical Factors.

(1) Missile Employment Opportunities.

BVR		VID	
F-15	Threat	F-15	Threat
13	1	8	8

Fig. 14. Missile Employment (2 Versus 2)

(2) Missile Employment Sequencing.

(a) Under BVR. The F-15s employed thirteen missiles prior to the threat aircraft having the capability to employ any.

(b) Under VID. The threat aircraft employed seven of the first eight missiles employed during the simulation.

b. Analysis. Against the highly inferior Type 1 threat aircraft (refer to comparison chart, Chapter III, Figure 10), the F-15s (under BVR) dominate the engagement. The F-15s employ the first thirteen missiles within the engagement. This provides two distinct advantages for the F-15s.

(1) It limits, due to defensive reaction necessitated by the F-15 employed missiles, the shot opportunities of the threat aircraft.

(2) It provides thirteen opportunities to reduce the threat formation size. Figure 15 depicts the probability of reducing the threat size by at least one aircraft for varying F-15 missile reliabilities. (Missile reliability is defined, in this context, as the probability of the missile fusing within its lethal radius of its target.) The graph assumes two missile fusings within lethal radius are required to kill the target.

From the graph, if the F-15 missile reliability is .5 (i.e., 50 percent of the time, a missile launched

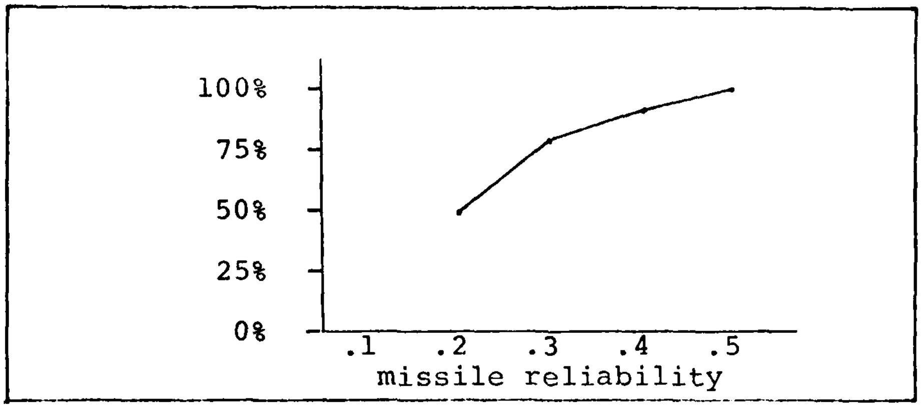

Fig. 15. F-15 First Shot Attrition Capability:
2 Versus 2, Type 1 Threat

will fuse within its lethal radius of the target), then the F-15s have a 99 percent chance of killing at least one of the two threat aircraft prior to the threat employing any weaponry.

Conversely, under VID employment of the F-15s, Figure 16 depicts the threat's capability of killing at least one of the F-15s prior to the F-15s' effective use of weaponry.

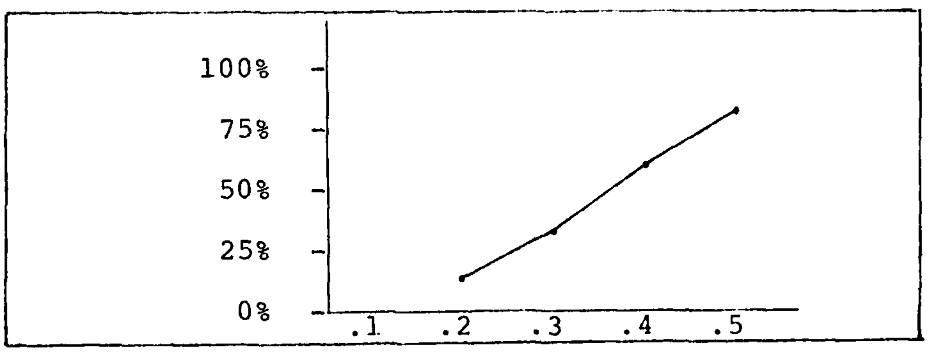

Fig. 16. Threat First Shot Attrition Capability:
2 Versus 2, Type 1 Threat

From the graph, if the threat's missile reliability is .5, then the threat aircraft have a 77 percent chance of killing at least one of the F-15s prior to the F-15s employing effective weaponry.

The F-15s were able to launch thirteen missiles under BVR, but only eight under VID. This represents a 38 percent reduction in missile opportunities. The threat employment opportunities increased 800 percent under F-15 VID-employment (from one to eight missiles).

2. Type 1 Threat Aircraft (2 versus 3).

a. Critical Factors.

(1) Against any numerically superior threat, the F-15s can not totally dictate the flow of the engagement through missile employment.

(2) Missile Employment Opportunities.

BVR		VID	
F-15	Threat	F-15	Threat
14	5	8	12

Fig. 17. Missile Employment (2 Versus 3)

(3) Missile Employment Sequencing.

(a) Under BVR. The F-15s employ twelve missiles prior to the threat aircraft having the capability to employ weaponry.

(b) Under VID. The threat aircraft employ more missiles than the F-15s during both the initial missile employment exchange and the final missile employment exchange.

b. Analysis. Again, under BVR employment rules of engagement, the F-15s demonstrate superiority in both radar and missile technology. Figure 18 depicts the probability of killing at least one of the threat aircraft prior to their employing weaponry.

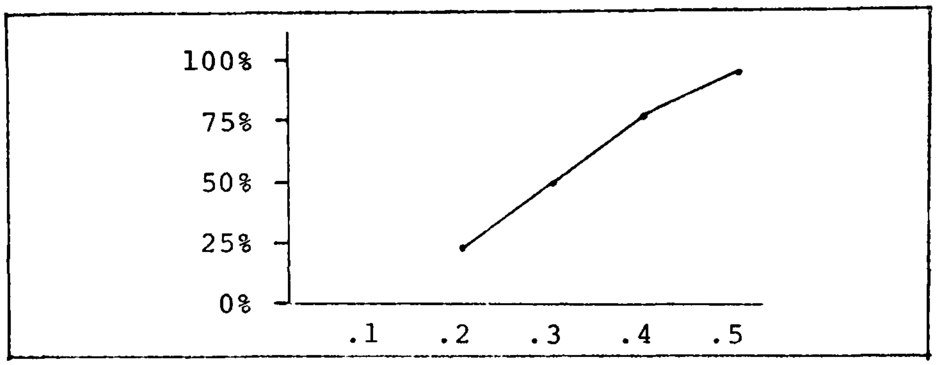

Fig. 18. F-15 First Shot Attrition Capability: 2 Versus 3, Type 1 Threat

From the graph, if the F-15 missile reliability is .5, then the F-15s have a 93 percent chance of killing at least one of the three threat aircraft prior to the threat employing weaponry.

Reducing the threat size from three to two aircraft provides the F-15s the opportunity to attack one versus one against the remaining threat aircraft. The superior performance of the F-15 provides the capability to dominate the engagement (as shown in the 2 versus 2 scenario) and prevent threat missile employment.

If the threat size is not reduced, the F-15's performance capability still provides advantages during one versus one maneuvering; however, there is always one threat aircraft that is not being attacked by the F-15s which can position to employ weaponry against the F-15s.

Under VID F-15 employment, the opportunity to reduce the threat formation size is not available. The threat aircraft demonstrate more missile employment capability than the F-15s. Unlike the 2 versus 2 scenario, in which the F-15s achieve missile employment dominance during the latter stage of the engagement, the 2 versus 3 scenario depicts the influence of the third threat aircraft in negating the superior performance capability possessed by the F-15. The shot exchange ratio during both the initial and the latter states of the engagement favors the threat aircraft.

Initial	6 to 4
Latter	6 to 4

Fig. 19. VID Shot Exchange Ratio (2 Versus 3)

The F-15 missile employment opportunities dropped under VID employment to eight missiles. This represents a

43 perc nt decrease in F-15 missile employment, while the threat's missile opportunities increased 140 percent.

3. Type 1 Threat Aircraft (2 versus 4).

a. Critical Factors.

(1) Missile Employment Opportunities.

BVD		VID	
F-15	Threat	F-15	Threat
16	10	12	10

Fig. 20. Missile Employments (2 Versus 4)

(2) Missile Employment Sequencing.

(a) Under BVR. The F-15s launched eleven of the first thirteen missiles employed during the simulation.

(b) Under VID. The threat aircraft launched four missiles prior to the F-15s employing weaponry.

b. Analysis. Figure 21 depicts the probability of the F-15s reducing the size of the threat formation by at least one aircraft, given employment under BVR rules of engagement.

From the graph, a .5 F-15 missile reliability provies a 89 percent chance of killing at least one of the threat's four aircraft prior to the threat's employment of effective weaponry.

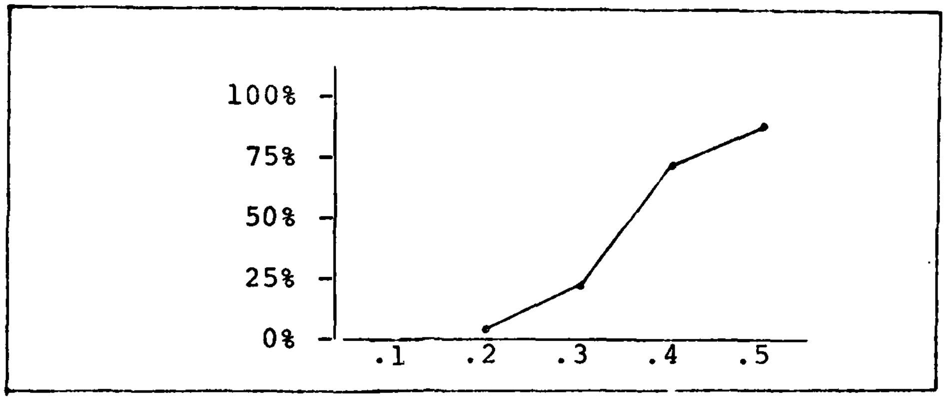

Fig. 21. F-15 First Shot Attrition Capability: 2 Versus 4, Type 1 Threat

Under VID, the F-15 missile opportunities are reduced 25 percent. Also, given a threat missile reliability of .5, the threat have a 31 percent chance of killing at least one of the two F-15s prior to F-15 missile employment.

4. Type 3 Threat Aircraft (2 versus 2).

a. Critical Factors.

(1) Missile Employment Opportunities.

BVR		VID	
F-15	Threat	F-15	Threat
16	4	12	8

Fig. 22. Missile Employment (2 Versus 2)

(2) Missile Employment Sequencing. Under VID F-15 employment, the threat aircraft employ 5 missiles prior to F-15 missile employment.

(3) Under BVR F-15 employment, it requires 50 seconds of maneuvering for the F-15s to assume dominance of the engagement; whereas, under VID, it requires 105 seconds of maneuvering.

b. Analysis. Against the inferior performance, but equal avionic/missile capable Type 3 threat, F-15 BVR employment demonstrates two advantages:

1. It limits, due to the threat aircrafts' defensive reaction to F-15 missiles employed, the missile employment opportunities of the threat (from eight to four missiles).

2. It allows for dominance of the engagement at an earlier point in time which provides for shorter engagements. The size of the F-15, as compared to the size of the threat counter-air aircraft, greatly reduces F-15 survivability as the length of the engagement increases.

Under VID F-15 employment, Figure 23 represents the probability of at least one F-15 being killed prior to employment of weaponry.

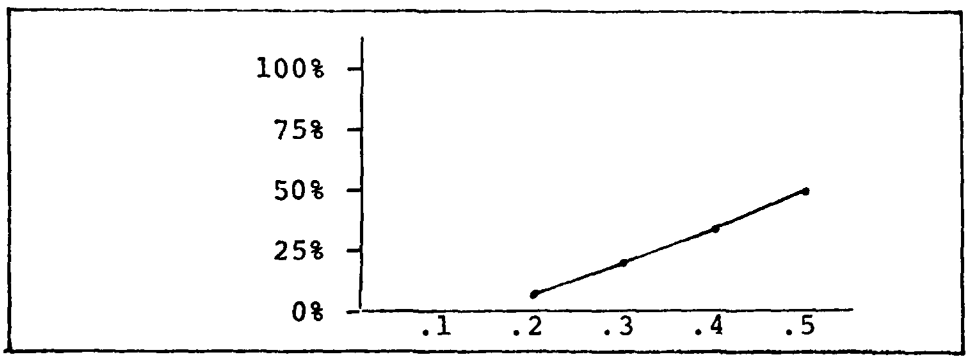

Fig. 23. Threat First Shot Attrition Capability: 2 Versus 2, Type 3 Threat

From the graph, if the threat missile reliability is .5, then the threat have a 50 percent chance of killing at least one of the two F-15s prior to F-15 weapons employment.

Also, under VID-employment, F-15 missile opportunities are reduced 25 percent, while threat employment opportunities increase 100 percent.

5. Type 3 Threat Aircraft (2 versus 3 and 2 versus 4).

a. Critical Factor. Missile Employment Sequencing.

(1) During 2 versus 3, VID F-15 employment; the threat aircraft have nine missile employment opportunities prior to F-15 weapon employment.

(2) During 2 versus 4, VID F-15 employment; the threat aircraft have ten missile employment opportunities prior to F-15 weapon employment.

b. Analysis. These two formation size engagements are grouped together due to similarities in F-15 employment tactics and results against three and four enemy aircraft formations. Equal avionic/missile capabilities provide for equal missile exchange ratios (per aircraft) until the F-15 performance advantage over the threat aircraft provides for F-15 dominance in the engagement.

Figure 24 depicts the dominance of F-15 performance capability over the threat aircraft. For example,

	BVR	VID
2 V 3	last 10	last 11 of 12
2 V 4	last 9 of 10	last 10

Fig. 24. F-15 Dominance in Aircraft Performance

the F-15s employ eleven of the last twelve missiles during the 2 versus 3, VID employment engagement.

However, prior to utilizing the performance advantage, the F-15s must survive the intercept portion of the engagement. Figure 25 indicates the probability of at least one of the two F-15s being attrited prior to employment of weaponry.

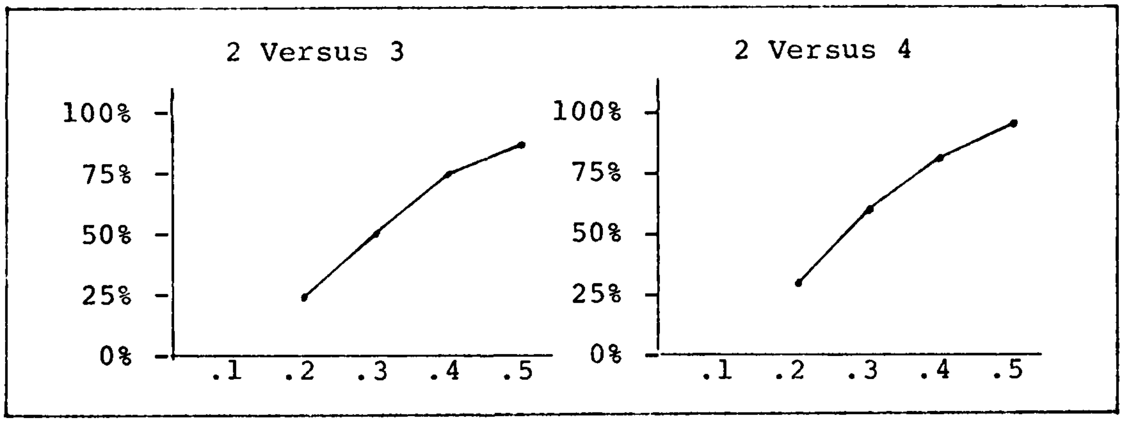

Fig. 25. Threat First Shot Attrition Capability: 2 Versus 3/4, Type 3 Threat

From the 2 versus 3 (2 versus 4) graph, given a .5 threat missile reliability rate, the threat have a 91 percent (95 percent) probability of killing at least one of the F-15s prior to F-15 weapon employment.

Bomber Threat

In analyzing the effect of the VID constraint on F-15 effectiveness against low-altitude bombers, the following engagements were evaluated: (bombers were employed at 200 feet above ground level and were removed from the engagement when their respective Probability of Survival, P_s, decreased below 25 percent.)

1. 2 versus 2, 350 knot Bomber Penetration Airspeed.

a. Critical Factor. Missile Type Utilization.

b. Analysis. Both BVR and VID F-15 employment were extremely efficient at this bomber penetration airspeed. Figure 26 depicts respective bomber P_s at the termination of the engagement.

	BVR	VID
1st bomber	.113	.234
2nd bomber	.235	.169

Fig. 26. Bomber P_s, 2 Versus 2, 350 Knots

The primary difference in the two employment doctrines was the type missiles employed to achieve the bomber kills. In the BVR engagement seven of the eight missiles employed to achieve kills on both bombers were radar missiles (i.e., long-range, all aspect missiles); whereas in the VID engagement, five of the seven missiles utilized to kill both bombers were the heat-seeking missiles (short-range, all aspect missiles). The time required for the BVR and VID engagements were 80 seconds and 65 seconds, respectively.

2. 2 versus 2, 500 knot Bomber Penetration Airspeed.

a. Critical Factor. Missile Type Utilization.

b. Analysis. At 500 knots bomber penetration, the BVR F-15 employment engagement was slightly more efficient than the VID F-15 employment engagement. The lengths of each respective engagement were set to the respective times in (1) above, which represent the time required to achieve kills on both bombers at 350 knots penetration. This was done to achieve a relative affect of speed on each specific ROE employment doctrine (see 3 below). Figure 27 depicts the respective P_s of each bomber at engagement termination.

	BVR	VID
1st bomber	.235	.248
2nd bomber	.317	.704

Fig. 27. Bomber P_s , 2 Versus 2, 500 Knots

Again, the BVR employment utilized primarily the radar missile (seven of ten) in achieving the P_k on the bombers; whereas the VID employment utilized more heat-seeking missiles (five of nine) during the process.

3. Comparison of Penetration Airspeed Affect on ROE.

a. Critical Factor. Bomber Penetration Airspeed.

b. Analysis. The effect of speed on the effectiveness of F-15 employment under both VID and BVR doctrines is depicted in Figure 28.

		BVR	VID
250 knots	1st bomber	.113	.234
	2nd bomber	.235	.169
500 knots	1st bomber	.235	.248
	2nd bomber	.317	.704

Fig. 28. Penetration Airspeed Effect (2 Versus 2)

Given a bomber threat of two penetrators, the requirement to VID does not appreciably reduce F-15 effectiveness for penetration airspeeds up to 500 knots. The reduction in F-15 efficiency is consistent within each ROE doctrine. Employment under both doctrines achieve one kill and at least one fusing on the second bomber during the prescribed engagement duration.

4. 2 versus 4, Comparison of Penetration Airspeed on ROE.

a. Critical Factor. Missile Employment Parameters.

b. Analysis. For the 2 versus 4 engagements, all were terminated due to the F-15s expending all on-board missiles. The results of the engagements are tabulated in Figure 29.

		BVR	VID
350 knots	1st bomber	.239	.293
	2nd bomber	.234	.234
	3rd bomber	.234	1.00
	4th bomber	1.00	1.00
600 knots	1st bomber	1.00	.217
	2nd bomber	.189	.236
	3rd bomber	1.00	.969
	4th bomber	1.00	1.00

Fig. 29. Penetration Airspeed Effect (2 Versus 4)

At the lower airspeed (350 knots) the results depict the VID constraint as reducing the F-15 effectiveness from three kills to one. However, at the higher airspeed (600 knots), the reverse is true--the VID improves the effectiveness of the F-15 from one kill to two.

The explanation of this apparent contradiction is derived from the missile employment sequencing. At the 350 knot bomber penetration airspeed, the better BVR results are achieved through proper employment of both the radar missile and the heat-seeking missile. The P_k of the AIM-7 (radar missile) is best during head-on geometrical employment. During BVR employment, the AIM-7s are utilized during the head-on portion of the engagement; however, under VID employment, the AIM-7s are launched in the bombers' stern areas.

At the 600 knot bomber penetration airspeed, the better results are also a direct function of the parameters of the missiles launched. In the VID engagement, the higher closing velocities between the opposing forces dictated the launching of ten of the sixteen missiles within 10,000 feet of their respective targets. The closer range employment improves the P_k of both missile types.

VI. Results

Counter-air Scenarios

Against the counter-air threat, the VID employment constraint completely changes the perspective of the engagement. Figure 30 depicts the dynamic change caused by the VID requirement.

	BVR	VID	NET CHANGE
F-15 missile opportunities	14	11	-3
Threat missile opportunities	7	10	+3
F-15 1st shots	6	0	-6
Threat 1st shots	0	6	+6

Fig. 30. Counter-Air Threat VID Effects

The values in the chart are average per engagement. This assumes an equal number of engagements against the two threat types, as well as an equal number of engagements against sizes of formation (i.e., the chart depicts the reduction of F-15 capability against an equal threat distribution).

The results depict the F-15 as superior to the threat in performance capability (visual range employment is eleven to four in favor of F-15); however, the threat averages six missiles employed prior to F-15 employment of weaponry. Figure 31 depicts the probability of attriting at least one F-15 prior to F-15 employment of weaponry per engagement.

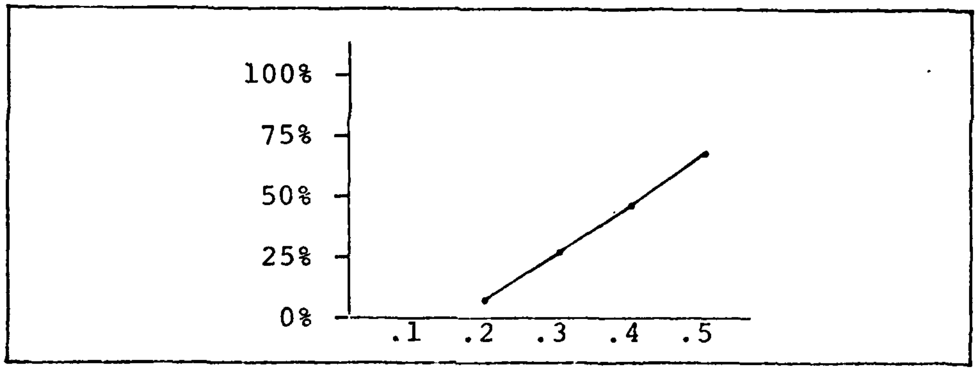

Fig. 31. Counter-Air Threat--First Shot Attrition

From the graph, given a .5 threat missile reliability, there exists a 66 percent chance of the threat attriting at least one of the F-15s prior to F-15 weapon employment.

Conversely, the same graph depicts F-15 attrition capability against threat aircraft given BVR employment.

Therefore, under VID employment against the counter-air threat spectrum, the F-15 will attain an equitable number of shots, provided all the enemy's first shot opportunities are ineffective. If not, the remaining single-ship F-15 will have an extremely difficult time being effective against the imposing threat.

Figure 32 represents VID affect on each specific threat.

	BVR	VID	NET CHANGE
F-15 missile opportunities	14	9	-5
Type 1 missile opportunities	5	10	+5
F-15 1st shots	12	0	-12
Type 1 1st shots	0	4	+4
F-15 missile opportunities	16	13	-3
Type 3 missile opportunities	8	10	+2
F-15 1st shots	0	0	0
Type 3 1st shots	0	8	+8

Fig. 32. Counter-Air: Type 1/3 VID Effects

Against each specific threat type:

1. Agsinst the Type 1 threat, the VID requirement transforms a vastly superior weapon system into less than the equal of the Soviet first and second generation composite aircraft.

2. Against the Type 3 threat, the VID requirement provides the threat aircraft first shot opportunities. Figure 33 depicts the probability of the threat killing at least one of the F-15s prior to F-15 weapon employment.

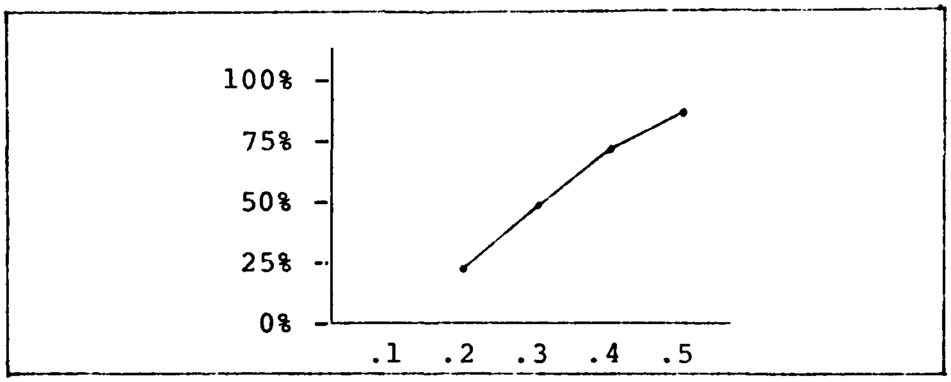

Fig. 33. Counter-Air Threat: Type 3, First Shot Attrition Capability

Bomber Defense Scenarios

Against the bomber threat, the VID versus BVR employment comparative analysis revealed an important missile employment doctrine: effective missile employment against low-altitude bombers consists of employment of the AIM-9 (all aspect, heat-seeking missile) initially and then subsequent missile employments as required to achieve maximum success against the bombers.

This doctrine provides the following advantages to the F-15s:

1. It maximizes the number of AIM-7s available for use against the counter-air threat.

2. It maximizes the effects of employing the AIM-7 under BVR. Against the counter-air threat, the BVR AIM-7 does not have to hit the target to have an effect on the outcome of the engagement. Conversely, a BVR AIM-7 launched at a bomber formation probably will not cause any effect unless it successfully fuses within its lethal radius against its target.

VII. Conclusions and Recommendations

Conclusions

The VID constraint, if imposed during the NATO conflict, will neutralize the effectiveness of the F-15s. As the bomber simulations depict, the above statement does not pertain to the VID affect on the capability of the F-15s to kill the bombers; but, rather reflects the ability of the F-15s to have the opportunity to engage the bombers. The enemy's use of escort/sweep tactics to provide support for bomber operations will achieve substantially higher F-15 kill rates if the F-15s are forced into the VID requirement. The limited inventory of F-15s postulated for NATO defense can not sustain high loss rates and subsequently provide the bomber defense required for NATO victory. The following conclusions are postulated from this study:

1. The F-15s must employ BVR against the counter-air threat.

2. Against low-altitude bombers, missile employment effectiveness can be maximized by appropriate missile sequencing during the engagement.

3. The effectiveness of the first and second generation Soviet fighters is greatly enhanced by the VID constraint on F-15 employment.

4. The numeric advantage of the Warsaw Pact forces is magnified by the VID constraint on the F-15 employment.

Recommendations

The assumptions and constraints employed within this study generate optimistic results. The effect of electronic jamming, elaborate enemy tactics, and technological advances in weaponry would further degrade F-15 effectiveness under VID. The following recommendations are submitted:

1. Review the priority for development of a "common-use" IFF system for the NATO theatre to ensure timely acquisition.

2. Expand VID versus BVR employment study to quantify the tradeoff between F-15 losses due to VID employment versus friendly aircraft inadvertently shot down due to BVR employment.

3. Continue development of PACAM 8 to provide for inclusion of mixed-force employment evaluation.

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Appendix

First-shot Attrition Calculations

The computation of the attrition capability associated with first-shot advantage is based on the binomial distribution. Each missile is assumed to be an independent event.

Example: assume the threat aircraft have six first shot missile opportunities. Also require that two successful missiles are needed to achieve a kill on each particular aircraft.

1. Three successful missiles must occur out of the six missiles launched to ensure that one of the F-15s is killed.

2. Assume a missile reliability rate. 1- reliability rate is the failure rate.

3. Substitute values into the binomial probability distribution function.

4. The probability of achieving at least one F-15 kill is (i.e., achieving three successes out of six trials):

$$1 - [P(\text{zero hits}) + P(\text{one hit}) + P(\text{two hits})]$$

5. In this example, assuming a .5 enemy missile reliability rate provides the threat a 66 percent chance of attriting at least one of the F-15s.

Vita

Danny R. Rogers was born on 28 October 1948 in Houma, Louisiana. He graduated from high school in Houma in 1966 and attended Nicholls State University from which he received the Bachelor of Science degree in Mathematics. Upon graduation, he received a commission in the USAF through the ROTC program. After completing navigator training, he served for approximately 1300 flying hours as a weapon systems' officer in the F-4 C, D, and E aircraft. In 1975 he was selected to attend pilot training. He completed pilot training in 1976 and subsequently has flown approximately 700 hours in the F-15 aircraft. The approximately 2000 flying hours include 950 hours of combat in Southeast Asia and numerous combined-force exercises (both Red Flag and Maple Flag). He entered the School of Engineering, Air Force Institute of Technology, in 1980.

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8