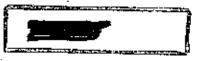
PART II

FIGHTER

 \mathbb{VS}

FIGHTER



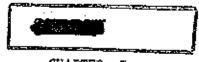
INTRODUCTION

In our discussion of fighter-versus-bomber tactics, you will recall, we determined the capabilities and limitations of our weapons systems. On having learned these parameters, we then developed our fighter-versus-bomber tactical doctrine. In our discussion of fighter-versus-fighter tactics, we will employ this same procedure. The order of discussion will be as follows:

- 1. Basic Limitations of ATM-9B Against a Maneuvering Target
- 2. Fighter Maneuvers
- 3. Tectical Formation
- 4. Flight Tactics

When analyzing fighter-versus-fighter tactics, by way of the four major phases above, we will employ the case system - a plan whereby we examine possible hypothetical situations which the pilot may encounter in fighter-versus-fighter combat.





CHAPTER I

BASIC LIMITATIONS OF ALM-9B AGAINST A MANEUVERING TAUGET

In discussing the employment of ALM-9B against a non-maneuvering target, we indicated that the missile has four basic limitations -IR, range, G, and lambda - and that these limitations forced us to deliver the missile in a cone 60° wide, emanating from the tail of the target aircraft. It was also shown that the length of this come would vary according to altitude and delta Mach. At high altitude, with a positive delta Mach, the cone (envelope) will be considerably longer than at low altitude. In our discussion of fighter-versusbomber tectics, we defined this cone in terms of angular velocity (max performance come). By angular velocity, come, we mean an envelope in which the attacking fighter may deliver AIM-9B without exceeding its maneuvering limitations. We can see, by applying this angular velocity come to any fighter-versus-bomber or fighter-versus-fighter situation, that the purpose of any tactics which we develop will be to place us in this come. On the other hand, when in a defensive situation, we will attempt to rotate this cone away from a given opponent. By doing this, we prevent him from securing a firing position.

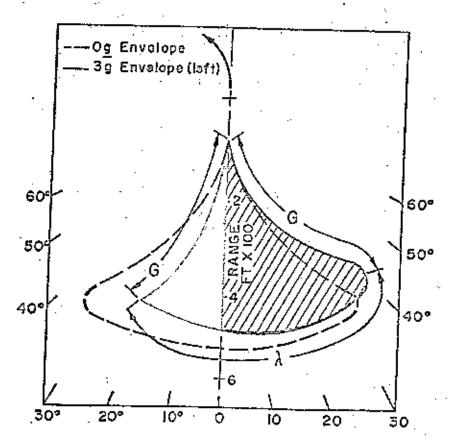
When employing AIM-9B against a manauvering target, the cone not only diminishes in size, it also changes in shape. In other words, the geometric shape of the maneuvering envelope will be considerably different than a non-maneuvering envelope. To illustrate: When discussing the non-maneuvering envelope, we found that its basic shape was determined by four factors - IR, range, G and lambda. We noted that these envelopes were rather symmatrical in shape. Maneuvering envelopes, on the other hand, are not so symmetrical. The lambda and G-limitations are primarily responsible for this change in shape. The reason for this: Lambda limitation may be exceeded because of a combination of low missile velocity and high angle off. If we launch AIM-93 from long range - within the effective range of the missile - at a maneuvering target, we can expect the target to turn into the attack. His objective is, of course, to rotate his angular velocity cone away from the launch sircraft. By doing this, the defender can force the missile to exceed its lambda limit, because the missile is not only slowing down as it approaches the target, but the angle-off is increasing, since the defender is turning into the missile's line of flight. In other words, the angular velocity generated by the defender forces ATM-9B to turn farther and farther in front of the target to maintain its collision course. This, of course, increases the resultant lembda angle. In addition, the missile is forced to turn even farther in front of the target, because of its continuous decrease in velocity after rocket motor burn-out, producing an extremely large lambda angle. If AIM-9B is launched near its max-effective range and the target turns into the ettack, the combination of increasing angle off and missile deceleration can easily cause the missile to exceed its lambda limitation. If



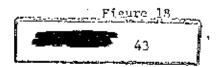


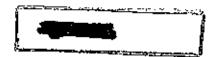
this occurs, the gyro seeker rubs against its mechanical stops, which stops the gyro and the missile loses guidance.

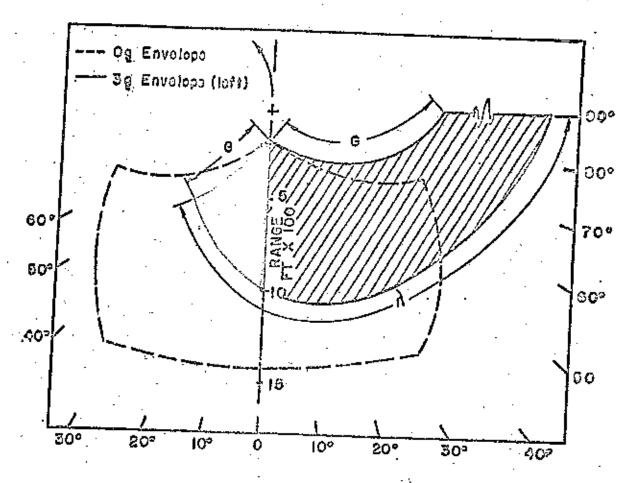
The attacker can do two things to avoid exceeding lambda limitation:
(1) Reduce his range before launch, which results in a higher missile velocity in relation to the target, and therefore, a smaller resultant lambda angle, and (2) reduce angle off. The smaller the angle off, the lower the resulting lambda angle. It is now obvious that the best attack can be initiated from the six-o'clock position at a reduced range. It is also obvious that lambda is the greatest missile limitation against a maneuvering target. To illustrate the magnitude of this limitation, lets examine figures 18 and 19.



TGT-.8 MACH
ATTACK-.8 MACH
ALTITUDE - SEA LEVEL
MANEUVER 3g LEFT TURN





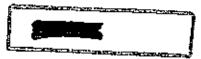


TGT - 1.0 MACH ATTACK - 1.0 MACH ALTITUDE-35000' TGT MANEUVER-36 LEFT TURN

Figure 19

When AIM-9B is launched from a .8 Mach attacker against a .8 Mach maneuvering target which is performing a 3-G turn into the attack, we note (from figure 18) that effective missile range is somewhat less than that available against a non-maneuvering target. We also note that max angle off from which AIM-9B may be launched is less than 20°. The reduction in range is necessary because of the 25° lambda limit, while the reduced angle off is caused by a combination of lambda and G-limitations (G-limitations will be discussed later). If the target pulls more than 3 G, the maneuvering envelope will become even smaller.





At 6 G, there will be no point from which the attacker can fire the missile and schileve a kill. In other words, there will be no maneuvering envelope at all. If Alm-99 is Launched from a Mach-1 attacker against a Mach-I target, at 25,000 feet, we note the following: When the target performs a 3-6 turn into the attack, at missile larnch, the artacker must reduce his range by approximately one-third when firing from a six-o'dlock position (see figure 19). If the attacker launches at 30° angle=off, he must reduce his range by approximately one-half as compared to a non-meneroring terget - if he expects to get a kill. Once again, the reason for this reduction in range is lambda limitation. The attacker must reduce his range, by a greater magnitude, at 30° angle-off because missile lambda angle is increased by both high angle off and increased range. When the angle off is increased, range must be reduced to preclude twomading lambde limit, hence the difference in range reduction between a sero-degree angle off and a high-angle-off shot against a manaryaming tanget. Once again, if the target increases G, the maneuvering suvelope diminishes in size. At 6-G, there will be no maneuvering anvelope, therefore, the attacker cannot achieve a successful launch and kill against a target pulling 6 G.

Deen no distinction of margor speed in any of his maneuvers. If speed decay occurs, its attent countil any valid charge and the attack will no longer be co-speed. As a meaning, wheelie velocity will be higher in relation to the temper, and the meaning leads angle will be smaller, since velocity resides invariant velocity will be smaller, since velocity resides invariant velocity will be smaller, since velocity resides invariant velocity and a given range and angle off). This means that if the attacker has a positive delta Mach, rester that a respect relationship, he can launch at a greater range without exacting launch stationship, he can launch at a greater range without exacting launch spained a measurering target which is traveling flation than the sole of a measurering target which is traveling flation than the sole of a measurering target which is the target, is smaller. Sandle: The attacker must launch at a shorter range to preclude lambde limits used.

In view of the shore meleticoships, we can see that the best attack is one in which the attacked has a positive delta Mach and a low angle-off on his initial approvab no the target. This will provide greater freedom of memorian and the opportunity to lammab at longer ranges. On the other hand, the worse possible attack is one in which the attacker has a negative delta back and a high angle-off. This will restrict his freedom of managers and force aim date a position from which the terget can easily defend egainer this attack.

If ATM-9B is leumoned from an extent executed in the vertical plane - overhead or underside attack - the maneuvering target will be forced to turn into the attack. Case again, by turning into the plane of the attack, the target will generate men engular velocity and force the missile to operate mean its limiting permaneters. In an overhead attack, this means that the enterper will not only be concerned with

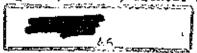


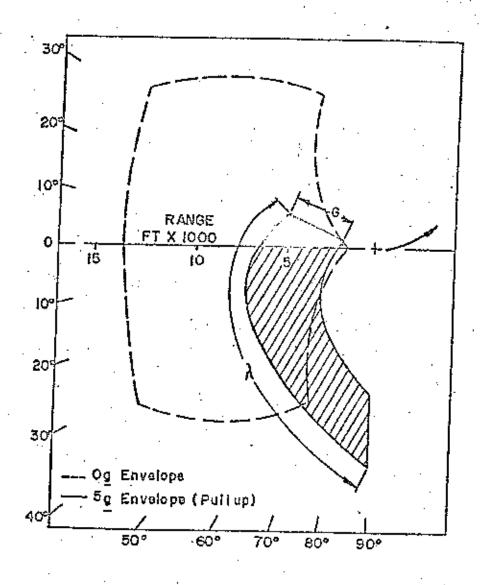


lambda limitation, but also with the same limitations encountered in an attack against a non-monouvering target - IR and G. These limitstions force the attacker to diminish his range until he can discriminate between IR background clutter and target signal and/or avoid exceeding the lambda limitation. This means that in a .9 Much co-speed attack against a maneuvering target, the attacker will be forced to fire at less than 20° engle-off, otherwise, he will exceed his 2G limitation. (see figure 20). Remember, in an overhead attack, the difference between total and radial G is considerably less than in the high-side or the underside attack (Gt = $Gr + Cos\theta$), therefore, to stay within the 2G limitation, the attakeer must launch from longer ranges (at a given angle-off). For example, if an attacker performs an overhead .9-Mach co-speed attack - to prevent himself from exceeding the 2G launch limitation at 300 angle-off - he must launch from a range of at least 10,450 feet. Under the same conditions, he can launch from a range of 6.840 feet at 30° engle off in a high-side or level attack. In an underside attack, he can launch as near as 4,130 feet at 30° angle-off and still be within the 26 launch limitation.

From the above analysis, it is apparent that the overhead attack is the worst possible because of the limitations imposed by IR, G and lambda. Unlike an overhead attack egainst a non-maneuvering target, the attacker will find it difficult to acquire the low angle-off necessary for launch. Instead, since the target is turning into the attack, the angle off will increase and the opportunity to lounch will be lost. On the other hand, there is a slight advantage since the torget is forced to furn into the attack - he will be forced to pull up and will consequently experience speed decay. The attecker will have a positive delta Mach and a higher missile velocity in relation to the target, and, therefore, a greater range from which he can launch AIM-93 before lambda limit is reached. This advantage is not a real advantage however, because the attacker can still be forced to exceed the IR and G parameters. We know, from our study of ATM-9B, that if we force the missile to exceed any one of the four parameters - IR, range, G or lambda - a kill will be unlikely. From a tectics standpoint, while con the defensive, the attack most easy to defend against is an overhead attack with a negative delto Mach. In this situation, we force the attacker to exceed a greater number of his limiting perometers than in any other attack.

The underside, or six-o'clock-low attack is the best possible attack which we can execute against a maneuvering target. It was noted in our analysis of this attack against a non-maneuvering target that we acquired advantages in IR, G, surprise, and performance. When attacking a maneuvering target, we retain these advantages, but acquire a disadvantage from lambde limitation. The lambde disadvantage is, however, everyidden by the advantages. This is two because the advantages of IR and G allow the attacker to levech at relatively shorter ranges at high angles-off, without exceeding the 2G levech





TGT - .9 MACH
ATTACK - .9 MACH
ALTITUDE - 55000
TGT MANEUVER - 5g PULL UP

Figure 20



limitation. (Remember, in an underside attack, radial G is greater than total G.) In other words, the attacker receives the benefit of IG gravity, thus allowing him to position himself closer to the target at a higher engle off without exceeding his 2G limitation (total G). This means that the attacker can reduce his range to stay within the lembda limitation and still be within his 2G launch limitation. In effect, the attacker is provided greater freedom of meneuver to successfully launch AIM-9B. In an underside attack, this freedom of maneuver is greater than in any other attack. From the defender's viewpoint, it is certainly the most difficult attack to defend against. In summary we may say: The best attack for AIM-9B is the underside attack and the worst attack is the overhead attack - especially if the attacker has a negative delta Mach.

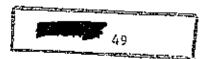


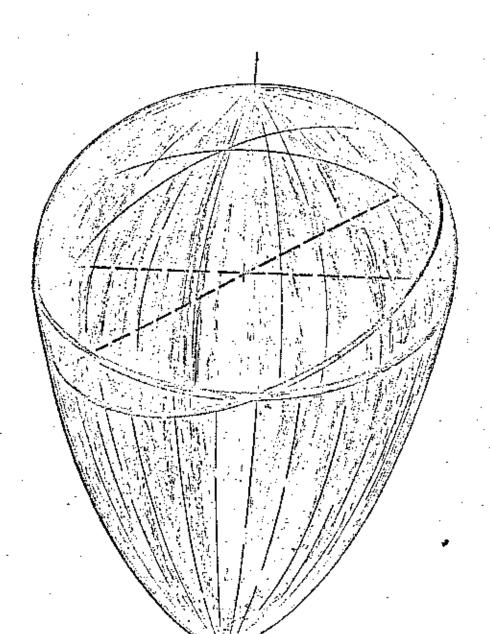
CHAPTER II

FIGHTER MANEUVERS

To acquire an understanding of the science of fighter-versusfighter combat, a complete knowledge of the spatial relationships involved in this form of serial combat, is necessary. Before he can
achieve this understanding, any tactician must be able to define or
imagine a frame of reference, within which he must operate. In addition, he must know the basic tools which he may employ in this frame
of reference. Simply stated, this means that the pilot must understand the geometric space relationships and how to apply this insight
to a given fighter-versus-fighter situation. Our purpose, in fighter
maneuvers, will be two-fold: (1) To define and present geometric relationships needed for fighter-versus-fighter combat, and (2) to show
how to properly apply these relationships in fighter maneuvers.

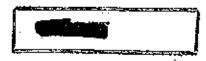
In discussing Eighter-versus-fighter combat, it is evident that many pilots believe there are an infinite number of situations and solutions in a given tactical encounter. Such is not the case! The field in which a fighter pilot must operate is three-dimensional and finite. The size and shape of the field is determined by the pull of IG gravity and the performance limitations of the aircraft and its pilot. We cer imagine this field to be spherical in shape, with a flattened northern hemisphere and an elongated southern hemisphere. See figure 21. The spherical shape is generated by a maneuvering fighter's turn and velocity operating through three dimensions. The elongation results from the effect of 1G gravity on the fighter in this three-dimensional field of maneuver. Turn, speed and the force of gravity determine the operating envelopes and we need only understand special relationships presented by these factors to develop effective fighter maneuvers. To know how to secure an adventage over an opponent, an attacker need only visualize turn, velocity and G projected onto this speroid shape. He has no control over the force of gravity, of course, but he can exercise complete control over aircraft ture and velocity. As a result, he can maneuver in a manner to effectively use the pull of gravity in a given tactical situation. Thus, in a fighter-versus-fighter situation, the pilot can do two things to gain an advantage over an opponent: Change turn and/or velocity, in respect to his opponent. He can accomplish either or both by maneuvering through both the vertical and horizontal planes by employing either a two-dimensional maneuver through three-dimensional space, or a threedimensional maneuver (barrel roil).





FIELD OF MANEUVER

-Figure 21

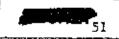


To apply these principles correctly, we need only recall what we determined previously in regard to weepons capability. We determined that to successfully employ APM-98 or the 20mm cannon, we must attain a launch or firing position in the angular velocity cone emanating from the tail of our opponent. Applying the three-dimensional concept of turn and velocity, this means that we must reduce one or both of these factors in order to secure an adventage. Employing these spatial relationships against a given opponent will provide insight as to the type of maneuver which we must employ to defeat him.

In our discussion of fighter maneuvers, we will keep in mind this concept of turn and velocity within a three-dimensional field. As stated earlier, we will use the case system to determine not only what maneuver to employ, but also how to employ it to acquire maximum benefit. In discussing fighter-versus-fighter tactics, our first maneuver for discussion will be the defensive turn. We choose to start with this maneuver because it is the basic maneuver by which the defender tries to nullify an attacker's advantage. This may cause our approach to appear to be defensive in nature, however, we feel that this is necessary since any offensive action is directly dependent on the precise maneuver which the defendant chooses to execute. If the defender's knowledge is limited in scope, the attacker's corresponding maneuvers will reflect this limitation.

Defensive Turn

The purpose of the defensive turn is to prevent an opponent from achieving a launch or firing position. As stated earlier, the objective of this maneuver is to rotate our angular velocity come away from the attacker. The best way to achieve this is to turn into the plane of the attack. This means that in an overhead attack, we will pull up into the attack; in an underside attack, we will dive into the attack; and if the attack is from six-o'clock, we will turn in whichever direction provides the greatest inctical advantage. Assuming that an attacker armed with an IR missile is approaching our angular velocity cone from six-o'clock, how would we defend against this attack? First, perform a hard turn with a slight dive. This turn should not be a / break or maximum performance maneuver. If so, we will experience high speed-decay end loss of maneuvering potential, eventually diminishing our angular velocity. As a result we will probably successfully defend against the missile attack, but our attacker will be in position for a follow-up gun attack. If we employ the hard turn and the slight dive, we generate erough angular velocity to preclude a missile launch at long range, and at the same time, we retain future maneuvering potential. As range diminishes, the attacker will be looking for an opportunity to launch a missile; however, since he is in a pursuit curve attack, his rate of turn is a function of target speed, angleoff and rangs. At-long range the rate of turn required for the attacker to track is considerably less than ours. Consequently, the attacker's





angle-off and rate of closure will increase. The increase in angle-off demands a further reduction in range before the attacker can successfully launch without exceeding the lambda limitation. This forces the attacker to get closer and, since he is on a curve of pursuit, his angle-off is continuing to increase as his range decreases. The rate of turn formula (W= Vt x Sin0) indicates that Range

rate of turn will increase if engle-off increases (Sin0) and range decreeses on an attack against a maneuvering target. Both of these conditions occur. This means that the attacker generates a rapid build-up in his rate of turn, and by the time he reaches the point at which he can launch without exceeding lambda limit, he exceeds the 2G launch limitation. With a .9-Mach co-speed attack at 35,000 feet, this will occur at a range of about 7.000 feet from the target. If the attacker gets closer, he must forego a missile attack and attempt to set up a 20mm cannon attack. This is necessary because when attacking a maneuvering target, once the G-limit is exceeded, G cannot be reduced - it will continue to build up as range diminishes.

As a defender, we are now forced to nullify our opponent's subsequent gun attack. To accomplish this, let us once again analyze our relative positions: The attacker, noting that he has lost the opportunity to deliver a missile, will attempt to reduce his angle-off and slide into our sin-o'clock position. To prevent this, we must increase G and rotate our angular velocity cone away from our opponent. Our concern now is to acquire a smaller turn radius than the attacker. This will force him outside our turn and prevent him from achieving a tracking solution. To accomplish this objective, we must play the turn in respect to the attacker. The moment we notice his attempt to diminish angle-off, we increase our G, to prevent him from diminishing his angle-off and sliding toward our six-o'clock position. If he continues to press the attack, tighten the turn to prevent him from staying on the inside of the turn. In effect, we are trying to place him on the other side of our angular velocity cone. If we play this maneuver correctly, he will be unable to match our turn radius. The formula for turn radius:

$$R = \frac{vf^2}{32.2N}$$

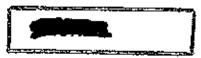
where R = Turn radius in feet

Vf = Fighter velocity in feet/second "

N - Number of radial G

indicates that the fighter with the lower velocity and/or greater G has a smaller term radius. In this situation, the attacker's speed and G are directly dependent upon the defender's action and if we pull a certain number of G, the attacker cannot pull the same amount. If he does, his rate of turn will equal ours, and, at the end of a





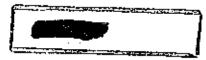
180° türn, the attacker becomes the defender and we the attacker. Of course this will not occur, because the attacker will be forced to play his turn in respect to our position. This means that his G will be less, and as a result, his speed decay will not be as rapid as ours. As is shown by the above formula, the attacker will have a greater turn radius for two reasons: (1) higher speed, and (2) lower G. As a result, if the attacker continues to press the attack in the plane of our turn, he must overshoot. This provides the attacker little opportunity to track the target and places him, geometrically, on the other side of our flight path. Of course, this presupposes that we, as the defender, are turning near or at maximum rate. If not, the attacker would be able to slide toward 6-o'clock, pull a higher G, diminish air-speed and avoid an overshoot. As we will see later, the lateral separation provided by this overshoot is a "must" for the defender's subsequent actions.

Procedures for the Defensive Turn

- 1. Estimate range and angle-off of the attacking aircraft.
- 2. Perform a hard turn if the attacker is near AIM-9B launch range. This is a planned maneuver to preclude a successful missile launch.
- 3. Do not make an instantaneous max-performance turn. This will kill off airspeed very rapidly and reduce future angular velocity as wall as maneuvering potential.
- 4. Play the turn to maintain the attacker at a high angle-off. This will force him to diminish his range and exceed the 2-G launch limit, at about the time when he is within lambda limit.
- 5. Increase rate of turn steadily to maximum performance as the attacker approaches gun-firing range. This will prevent him from acquiring a tracking solution and sliding toward your six-o'clock position.

Adverse Yaw

Adverse yaw is defined as the tendency of the aircraft to yaw or roll away from the intended turn. In the F-100, this condition is present in the sub-sonic speed range, and is especially noticeable in high-angle-of-attack maneuvering. If proper technique is not employed to counteract adverse yaw in high-angle-of-attack maneuvers, aircraft maneuverability is seriously compromised. In fighter-versus-fighter combat, since maneuverability is a key to success, inability to hendle adverse yaw will produce disastrous results. We can see this upon examining the defensive turn. In defending against an AM-9B attack, the speed and G which we were pulling produced a low angle of attack. Defending against a follow-up gun attack, however, produced a high

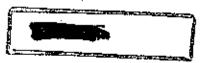


angle of attack. If conventional technique is attempted when max performance is necessary, the result will not be maximum performance. To preclude performance degradation, the pilot must develop two entirely different techniques to control the F-100 under low-angle-of-attack and high-angle-of-attack conditions.

In low-angle-of-attack maneuvers, conventional technique will be employed. That is, allerons will be primary control for directional change, in either a turn or a roll, and rudder will be secondary. It will be used to counter the small amount of adverse yaw to keep the turn or roll coordinated. Each pressure will be employed to control the rate of turn or the intensity of the roll.

In high-angle-of-attack maneuvers, the following techniques will be employed: Rudder will be used to control directional change. Allerons will be moved to the neutral position and back pressure will be employed to control the rate of turn or intensity of the roll. In a high-angle-of-attack situation, if the pilot employs alleron as priwary for directional change, he will induce a roll-off in the direction away from the intended turn. The more alleron he applies, the faster the roll-away. This is true because, in a turn, the induced drag on the inboard wing is less than that on the outboard wing. If afteron is employed, the inboard afteron is deflected up and the outboard aileron is deflected down. This condition imposes an additional increment of drag upon the outboard wing. As a result, the aircraft yaws toward the high-drag area, or in a direction away from the intended turn. In low-angle-of-attack maneuvers, this yaw can be corrected by applying rudder until the ball is centered. In a high-angle-of-attack maneuver with the F-100; this technique is not satisfactory. As the angle of attack increases, the amount of adverse yaw generated by the induced drag and deflected ailerons increases. The yaw increase causes the outboard wing to meet the relative wind at a velocity less than the inboard wing. The decrease in velocity, plus the downward deflection of the outboard aileron, causes the aileron to stall out, consequently, there will be less lift over the outboard wing. The aircraft will roll in the direction of the yew. If additional aileron is applied to correct this roll-off, the rate of roll will increase and the adverse yaw and stall conditions will be magnified. If rudder is employed - along with aileron - the adverse yew generated may be cancelled by the favorable yew induced by the rudder. However, as the angle of attack builds up, the adverse yaw generated by induced drag and deflected sileron becomes greater than the favorable yaw generated by the rudder. Thus, a roll-off will still occur, however, at a slightly higher angle of attack. On the other hand, if we neutralize aileron and employ gudder as primary for directional control, we can generate a maximum performance turn without a subsequent roll-off.

To determine whether we should use conventional techniques or the rudder rechnique, we need only recognize the "feel" of the aircraft. The moment the outboard wing approximately heavy, the pilot should

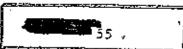


neutralize aileron and apply rudder to control the turn or roll. Full rudder should not be employed, otherwise the pilot will experience a loss of directional control. Instead, apply rudder smoothly and as needed to maintain directional control. If this is accomplished, the ball will be centered and a max-performance menauver is possible. Do not arbitrarily use full rudder and opposite aileron to achieve a max-performance turn. If this is accomplished, a large amount of favorable yaw will be generated and a snap-roll or spin will probably occur.

The Scissors Menauver

The scissons is a defensive maneuver in which a series of turn reversels is executed in an attempt to schieve offensive potential after an overshoot by an attacker. To successfully employ the scissors, the defender needs an initial turn overshoot. In a defensive turn, if an attacker attempts to position himself in his opponent's angular velocity come by remaining in the plane of his turn, the defender is provided the opportunity to generate an overshoot. The overshoot places the attacker on the opposite side of the defender's angular velocity come. If the defender continues to turn in the same direction after the overshoot, the attacker will be presented the opportunity to maneuver toward his opponent's six-o'clock position, simply because the defender will be turning away from the attack. To prevent this, the defender must initiate a turn reversal as the attacker passes through his flight path. The decision as to when to execute this reversal will depend upon the attacker's rate of overshoot and his angle-off. A good "rule-of-thumb" is: rapid turn overshoot, early reversel; slow turn overshoot, late reversal. The turn reversal will rotate the defender's angular velocity come away from the attacker. This will place the attacker at a high angle-off and will cause him, once again, to cross the defender's flight path. See figure 22. The defender has now forced the attacker into a scissors

We can see - by geometric inspection - that the aircraft which has the shorter turn radius and the lower velocity, will force the other to the 12-o'clock position. In this maneuver, the defender has the advantage. By virtue of forcing the attacker to overshoot, he has lower velocity and if he employs the proper technique, he can easily place the attacker at 12-o'clock. To accomplish this, each turn reversal should be a rudder reversal, at max-performance. If eileron is applied, the defender will roll off in the wrong direction, or be forced to release back-pressure to execute the reversal. This, of course, will increase turn radius. A nose-high attitude accomplishes two things: (1) It reduces the defender's horizontal turning component, and (2) It reduces the defender's vector velocity in the horizontal plane. The reduction in the horizontal turning component and vector velocity is a result of maneuvering through both the vertical and horizontal planes. In other words, we are employing the pull of





one-G gravity to provide a greater radial G and a lower velocity. Maximum power should be used in this maneuvar, because its force vector opposes the one-G gravity and is directed toward the inside of the turning circle. This provides the defender the opportunity to maneuver through the vertical plane, and thereby diminish his horizontal turning component. In addition, since power provides a lower stall speed, it allows the defender to tighten his turn radius at a given airspeed as well as reduce simpleed to the lowest possible point. This means that if the defender performs a nose-high rudder reversal with power on, he will reduce his turn and velocity components to their smallest state and, if the attacker doesn't counter in like manner, he becomes the attacker.

If the attacker counters affectively, and forces the defender below him, the defender should manager in phase with the attacker. This provides the stracker a visual disedvantage since the defender will be directly beneath him. In an attempt to manauver, in relation to the defender, the attacker will be forced to roll excessively in one direction or the other. This increases his stall speed and forces him forwand and down toward bis opposedn's filtent path. The moment the attacker noutces this, he probably will reduce his bank and meneuver as smoothly as the defender, with a regultant standoff. If, and when, this occurs, the defender must employ efferburner, relax G and dive 180° away from him opposers. To should initiate this manager is madfately after the attacker has made his fast observation, when the attacker done have visual content. This affords the defender the oppositionably to gain considerable longitudinal separation and places the aftendant in an owerhouse strack with a negative delta Mach. The defender will be out of gow range and the attacker will be provided the worst possible singular, for a missile larneh. (NOTE: Eactical enelysis of the diversway will be discussed later.)

When employing the sciences maneuver, a pilot should attempt to secure an adventage as quickly as possible - certainly by the second turn revenuel. If not, he will lose airspeed rapidly, therefore meneuverability, and will be prevented from ever acquiring an advantage. Instead, he will find himself in a standoff, with marginal control - an easy set-up for another attanker (or his immediate opponent, if the opponent has a superfor aircraft).

Procedures for the Scissons Meretimer

- 1. Undersets rate of turn into the attack until the attacker overshoots or moves outside the turn.
- 2. Execute a nose-high radder reversal with power on as the attacker passes your table. Remember the "rule-of-thumb" for turn-reversal: Espid turn overshoot, early reversal; slow turn overshoot, late reversal.

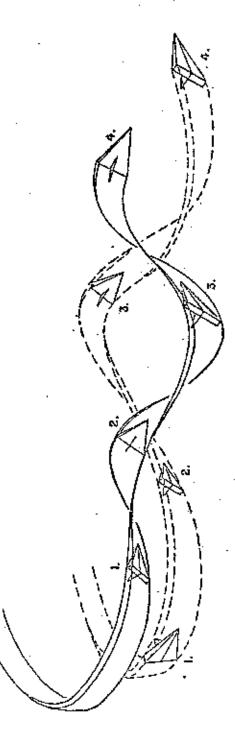
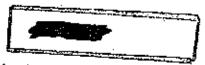


Figure 22



- 3. Repeat a nose-high reversal each time your opponent slides through your flight path to the outside of the turn. If you pass nose-high above your opponent, he will begin to slide forward.
- 4. Perform a roll-off or "S" down to the six-o'clock position, after you obtain a position above and behind your opponent.
- 5. Place yourself in phase with your opponent if you are underneath him; then, at the earliest possible moment, perform the 1800 dive-away.

Countering the Scissors Manauver

In our discussion of the soissors maneuver, we stated that it is a defensive maneuver designed to take advantage of an attacker's overshoot. We then proceeded to show how the defender would react to gain this advantage. The implication is clear - an attacker places himself in a very serious position if he misjudges the defender's turn and overshoots. To prevent this, it is suggested that the attacker employ the high-speed yo-yo any time he believes his rate of closure may be sufficient to cause a turn overshoot. In this manner, the attacker can retain his offensive advantage, however, we will still have the problem: What can an attacker do in the event he misjudges his oppoment's turn and is forced into an overshoot? The purpose in discussing maneuvers after a turn overshoot is to point out an effective counter to the scissors and, by means of this counter, show that the scissors is highly over-rated as an easy method by which to achieve an offensive advantage.

To know how to counter a scissors meneuver, we must first determine the attacker's maneuvering potential in respect to the defender: The attacker has a significant disadvantage in terms of velocity; however, this disadvantage can be converted to an advantage if the attacker knows how to employ it properly. Maneuvering into a nose-high acissors is not proper employment, as this will place him forward or above his oppoment in a stalemate condition. On the other hand, if the attacker employs this velocity in the vertical plane, in a zoom manauver, he can generate a significant advantage. How can this advantage be gained? As the attacker notes that he is overshooting his opponent's turn, he should relax G and deliberately slide around the outside of the turn. Relaxing G serves a two-fold purpose: (1) It reduces induced drag, thereby allowing the attacker to meintain an airspeed advantage, and (2) It increases lateral separation on the overshoot. This reduces the attacker's velocity component along the axis of his opponent's flight path, thus allowing the attacker to maintain nose-tail separation. The defender, observing the overshoot, will be enticed to execute a nose-high reversal in an attempt to gain offensive edventage. If the defender continues the turn, the attacker can play the maneuver and, once egain, slide into the defender's engular velocity come. In



view of this, a raversal is almost a sure thing. As the defender reverses, the attacker rolls wings-level and zooms, at a max-rotation-angle, through the vertical plane. See figure 23. The defender will be unable to match the attacker's rotation angle and subsequent zoom because of his airspeed disadvantage. This means that the attacker, even though he has a higher airspeed, may reduce his horizontal vector velocity to a smaller value than that of his opponent. As a result, the attacker will be on top with nose-tail separation, and the defender will have dissipated his airspeed, with a consequent loss of maneuvering potential. The attacker need only roll off to the defender's six-o'clock position.

If the defender pulls up into a banked attitude, toward the attacker's rotation, the height of his pull-up will be even less. This is the result of two factors: (1) The defender's pull-up is only a component of a straight pull-up - his rotation angle is through both the vertical and horizontal planes. Since he is in a banked attitude, this means that his rotation angle in the vertical plane must be less than a straight pull-up. (2) The defender's stall speed is higher. In a banked attitude, stall speed increases because less lifting surface is available to counter the pull of gravity. Figher stall speed causes the rotation component in the vertical plane to be even less. As a result of these two factors, the defender's rotation angle is reduced. This means that the height of the zoom in the vertical plane is less and vector velocity in the horizontal plane is increased. This forces the defender to turn below, in front of and across the attacker's line of flight. The attacker need only roll off in a direction opposite his opponent's turn and move toward the six-o'clock position. The roll-off increases nose-tail separation and prevents a possible overshoot by the attacker.

To manager against the attacker's counter, the defender simply cannot refuse to reverse and continue his defensive turn. If he does, the attacker will not be obligated to roll wings-level and zoom in the vertical plane. The defender will turn away and place his angular velocity come in front of the attacker's flight path. As a consequence, the attacker will simply play his opponent's turn and manager toward the six-o'clock position. If the defender cannot pull up and turn into, or away, how then will he meneuver against the attacker's counter? As the attacker overshoots his turn, the defender will execute a nose-high reversal. This will force the attacker to roll wings-level, rotate through a large angle in the vertical plane and zoom for altitude. action is designed to reduce vector velocity in the horizontal plane to a value less than the defender's velocity. If the attacker fails to generate this large rotation, his vector velocity will be greater, and he will be forced toward the defender's twelve-o'clock-high position. So we see, the attacker has no choice, he must rotate through a large vertical angle when the defender executes his nose-high cititude and provides considerable vertical displacement in respect to the defender. Having placed the attroker in this position, the defender turns 1800

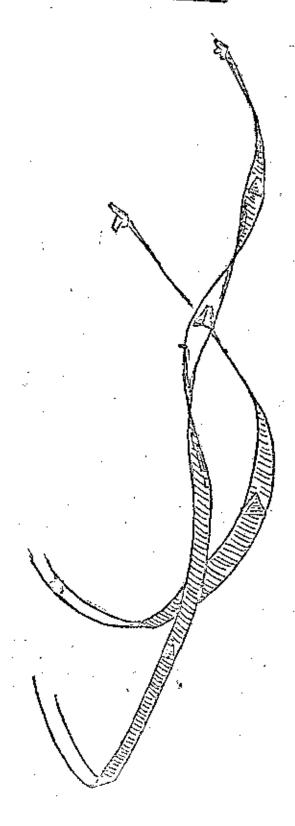


Figure 23



in the vertical plane, relaxes G, lights afterburner and dives for separation. (The defender must accomplish his turn before dissipating too much airspeed and acquiring an extreme nose-high condition.) Noting the dive for separation, the attacker must turn - from an extreme nose-high position - 180° in the vertical plane to regain an offensive position at six-o'clock. The pull of one-G gravity causes the attacker to dissipate considerable airspeed, thus placing him in an overhead attack with a negative delta Mach outside of gun range.

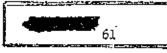
Remember: The counter to the sicssor maneuver is nothing more than a high-speed yo-yo initiated after a turn overshoot. The only difference is that the attacker relaxes G, rolls wings-level and zooms in the vertical plane, so that he may regain nose-tail separation.

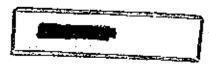
Procedures for Countering the Scissors Maneuver

- Realize that you are overshooting your opponent's turn and can no longer effect a yo-yo maneuver.
- 2. Do not attempt to pull into the target's radius of turn. This will impose high G-loads, and possible buffet or stall will occur. All airspeed advantage will be lost.
- 3. Relax G, slide around the outside of the turn, and thereby maintain an airspeed advantage.
- 4. <u>Roll level</u>, and zoom up (wings-level) as your opponent reverses into you. When your opponent reverses, he will be unable to match your zoom, because he will have killed some of his airspeed on the reversal, hesides having less airspeed to begin with.
- 5. Continue to pull up, wings-level, and force your opponent forward and below your line of flight. If he pulls up into a banked attitude, he cannot counter your maneuver, since: (2) His stall speed is higher, and (b) His pull-up is only a component of a straight pull-up. If your opponent pulls up wings-level, he cannot match our rotation, because of your airspeed advantage. In any case, your rotation in the vertical plane will be greater than your opponent's. This will place him below and forward of your line of flight. You will have nose-tail separation.
- 6. Roll off roll in a direction away from your opponent's turn if he is in a banked attitude and move into his six-o'clock position. The roll-off will provide additional mose-tail separation and will prevent a possible overshoot.

Procedures for Manauvering Against a Scissors Counter

1. Play the defensive turn in an attempt to force the attacker to overshoot your flight path.



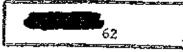


- 2. Reverse nose-high, as you observe your opponent overshooting your turn radius. Remember: A decision as to when to reverse will depend upon how rapidly the attacker is oliding to the outside rapid turn overshoot, early reversal; slow turn overshoot, late reversal.
- 3. Determine if your opponent rolls wings-level, rotates and zooms in the vertical plane or commits himself to the scissors meneuver. If he zooms in the vertical plane, follow the procedures below; otherwise employ the procedures specified for the scissors meneuver.
- 4. Force your opponent into an extreme nose-high attitude and a high resulting zoom, by pulling nose-high toward his line of flight. The attacker must rotate nose-high and zoom for considerable altitude to counter your nose-high pull-up. His purpose is, of course, to reduce his vector velocity in the horizontal plane in order to maintain nose-tail separation.
- 5. Turn 180° in a vertical plane, relax G, light afterburner and dive for separation. This maneuver should be initiated prior to dissipating too much airspeed otherwise, it will be difficult to gain separation. If done properly, the attacker will be placed in an overhead attack with a negative delta Mach outside gun range.

The Attack

The purpose of the attack is to position ourselves in the defender's angular velocity come, so that we may deliver our ordnance and effect a kill. Since the angular velocity cone of AIM-9B is considerably. greater than the 20mm come, we will first try for a set up to launch a missile. Knowing ATM-9Bs capabilities, we will try to attack our target from six-o'clock low. If the defender notes our position, we can expect him to perform a defensive turn into the attack so as to rotate his angular velocity come away from us. If he accomplishes this, we will be unable to successfully launch a missile because of its lambda limitation. Instead, we wil' be forced to diminish range until we reach a point where lambda limit will not be exceeded. If we attempt to fly a pursuit curve attack - track the target with our fixed sight -to this point, our angle-off will increase and a further reduction in range will be required before launch. By the time we reach the range at which we can launch without exceeding lambda limit, we will have exceeded the missile's 2G launch limitation. As we get closer, G will continue to build up and the opportunity to employ AIM-9B will be lost. We are now forced to initiate a gun attack.

Our position is not satisfactory for a gun attack: In our pursuit curve approach, we built up a substantial angle-off, but now we are faced with the prospect of diminishing this angle-off in order to reduce our angular velocity to enable us to track the target. As we attempt to accomplish this, we can expect the defender to tighten his





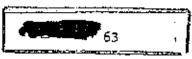
turn to prevent us from doing so. We, in turn, will be forced to counter. Result: If we continue the attack, in the plane of our opponent's turn, we will slide through his flight path and to the opposite side of the angular velocity cone. Under the circumstances, we can expect the defender to counter with a scissors maneuver. To prevent this, we have to employ a different technique in the initial attack.

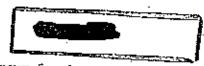
In the initial missile attack, the worst error which we can commit is to fly a pursuit curve attack - in other words, continuously track the target with our fixed sight in an attempt to launch AIM-9B. This forces us to continuously increase our angle-off and prevents us from ever launching. It also prevents us from salvaging the situation by initiating a gun attack. At the same time, the pursuit curve causes a turn overshoot and sets up the defender for a successful scissors meneuver. To prevent the defender from generating these favorable relationships, we should not fly our gensight (pursuit curve) after the defender initiates his defensive rurn. Instead, we should attempt to generate a rate of turn almost equal to that of the defender. (We must not match his rate of turn, for if we do, he will have rotated into the position of attacker at the end of 1800 of turn.) By doing this, we keep our flight path or fuselage in the same relative direction as the defender. In other words, we prevent the large increase in angle-off. This prevents us from launching ATM-9B; however, as we approach gun range, this positions us at a smaller angle-off and much nearer our opponent's angular velocity cone. To counter, the defender is forced to tighten up his turn much sooner than in a pursuit curve attack. This meens that the defender is forced to maintain a max-performance turn for a longer time period, in an attempt to generate an overshoot. This causes a greater speed decay, a loss of angular velocity and a loss of future meneuvering potential as we enter gun firing range. As a result, the defender has a more difficult time generating an overshoot and a subsequent scissors. If he exercises poor judgment and is lacking in stick and rudder technique, he may never effect the overshoot. The result is obvious: We simply shoot him down. On the other hand, if his judgment and slick and rudder technique are excellent, we will still be forced to overshoot if we continue to press the attack in the plane of his turn.

To prevent an overhacot, we should zoom or yo-yo off the defender if we are unable to stay inside his turn radius.

Procedures for the Initial Attack

- Stalk your target in an attempt to position yourself for a six-o'clock-low missile attack.
- 2. Do not attempt to track or launch ATM-9B at max-effective range, if the defender turns into the attack. Instead, position the guncight reticle shead of the target.





- Check that your fuselage is pointing in the same relative direction as the defender's fuselage. This will help prevent overshoot.
- 4. Continue the cutoff to close upon the target. However, attempt to gradually reduce angle-off as range diminishes, in an effort to launch a missile. If this is impossible, disregard the missile and continue the cutoff to set up for a gun attack.
 - 5. Play the cutoff, in an effort to reduce angle-off and slide inside the defender's 20mm angular velocity cone.
- 6. Press the attack until you realize it will be impossible to stay inside the defender's turn radius. At this point, zoom or yo-yo off the target to prevent overshoot and a subsequent scissors maneuver.

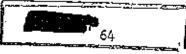
High-Speed Yo-Yo

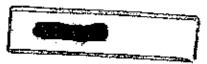
The high-speed yo-yo is an offensive tactic in which the attacker maneuvers through both the vertical and horizontal planes to prevent an overshoot in the plane of the defender's turn. See figure 24. From this definition, the purpose of the maneuver is obvious: To maintain an offensive advantage by keeping nose-tail separation between the attacker and defender. In other words, the high-speed yo-yo is a counter for the defensive turn and the scissors maneuver. As an attacker, when it becomes apparent that it will be impossible to stay inside the defender's turn radius, employ the high-speed yo-yo.

To perform the maneuver correctly, timing is essential. To illustrate: If an attacker is conservative and yowyo's high early, he can expect the defender to lower his nose and dive for separation. The defender, noting the early yowyo, realizes it will be foothardy to continue his turn or to pull up into the attack. If he continues the turn, the defender will dissipate his airspeed and his angular velocity. Consequently, the attacker will be permitted to reduce range and slide down into the defender's angular velocity cone. If the defender pulls up into the attack, he dissipates airspeed and angular velocity even more rapidly. Again, the attacker is provided the opportunity to diminish range and roll or slide into his opponent's angular velocity cone. The defender cannot counter, because he has no further maneuvering potential.

In view of the above, the defender's best maneuver is to dive away and gain separation. By doing this, he places the attacker out of gun range and in an overhead attack with a negative delta Mach - the worst possible attack with ATM-9B.

If the attacker yo-yo's late, it will be difficult for him to maintain nose-tail separation. He will either be directly on top of the





defender or will slide to the defender's twelve-o'clock-high position. If this occurs, we can expect the defender to reverse and pull up into the attacker. By doing this, he will dissipate his airspeed and reduce-his vector velocity along the horizontal exis, thus giving the defender the opportunity to maneuver toward the attacker's six-o'clock-low position. The attacker now becomes the defender.

We can see that to maintain offensive advantage, the attacker must not be too conservative and yo-yo early nor too aggressive and yo-yo late. Rather, he must play the yo-yo for a middle position in order to prevent the defender from diving away or pulling up into the attack. Excellent timing and skillful stick and rudder technique are required to attain this position.

The moment the attacker realizes that he will be unable to stay inside his opponent's turn radius, he should roll away from the defender's turn and pull his nose through the vertical plane. The purpose of this action is to diminish his turning component and vector velocity in the plane of the defender's turn. To acquire max effectiveness, the attacker must maintain back pressure and employ rudder as primary control for directional change in the vertical plane. Por proper perspective, this means that the attacker rolls toward the vertical plane just enough to provide him an angle of bank smaller than that of his opponent. This forces the attacker's flight path to describe an ere through both the vertical and horizontal planes (we assume that the defender is turning, more or less, through the horizontal plane). As a result, the attacker's turning component and vector velocity are diminished in respect to the defender's turning and velocity components in the plane of the defender's turn. This allows the attacker to maintain nose-tail separation while turning inside his opponent. At the same time, the control technique employed - back pressure and rudder as primary control for the maneuver - not only allows the attacker to reduce his turn and velocity components to their smallest value, but also reduces his yo-yo apex. This provides the defender very little maneuvering freedom with which to counter the high-speed yo-yo. If the attacker does not use rudder as primary control for the roll into the yo-yo he will be forced to relax back pressure. His turn radius and velocity will increase and his induced drag will decrease. So, to maintain nose-tail separation and prevent a turn overshoot, the attacker will be forced to yo-yo to a higher apex point. This provides the defender the option of diving away to gain separation and, of course, places the attacker in an over-head attack with a negative delta Mach. If the attacker attempts to employ ailerons and maintain back pressure, adverse yew will preclude the yo-yo maneuver. As a result, the attacker will probably be forced to overshoot his opponent and will be caught in a scissors maneuver.

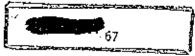
If the attacker employs the high-speed yo-yo correctly, the effect of one-G gravity on turn and valocity will provide nose-tail separation





with little vertical displacement - low yo-yo apex. The attacker need only roll or slide down to his opponent's six-o'clock position. The attacker should employ roll if he has little nose-tail separation. The roll reduces his vector velocity along the axis of the roll. This provides the attacker separation and thus prevents a possible overshoot. To perform the roll successfully, the attacker should continuously release back pressure as he rolls from 90° up to the inverted position - 180° - then gradually increase back-pressure as he approaches the 270° point and continue the increase of back pressure until the 360° point. From the 180° through to the 360° point, the attacker should employ top rudder. If the attacker fails to employ this stick and rudder technique, he will roll underneath his opponent in an obvious over-shoot - his offensive advantage seriously compromised. From our discussion of the high-speed yo-yo, we may have implied that this maneuver is the ultimate in countering a perfectly-executed defensive turn with a follow-up scissors. This is not the case. If the attacker yoyo's too far behind or too high, the defender can relax G, light afterburner and dive away for separation. This places the attacker in an overhead attack with a negative delta Mach. If the attacker yo-yo's high and maintains very little nose-tail separation, the defender can pull up into the attack and secure a six-o'clock-low position. If the attacker parfectly executes the high-speed yo-yo, the defender still has an out if he exercises excellent judgment and skillful technique.

To counter the high-speed yo-yo, the defender must first play the attack in an attempt to force an overshoot. Naturally, we can expect the attacker to yo-yo-high to maintain his advantage. The defender must now determine the attacker's relative position and atritude before making the next move. If the attacker generates extreme vertical separation, the defender must immediately relax G, light afterburner, and dive 180° away. If the attacker executes the high-speed yo-yo properly, the defender has little opportunity to dive away. If the defender pulls up, he will only position himself at 12-o'clock, and if he maintains his turn, he will dissipate his airspeed and angular velocity. The attacker will then merely slide down to his six-o'clock position and finish him off. To understand the counter which the defender must employ, let's examine the spatial relationship of the attacker in respect to the defender. The attacker, although in a most favorable position with his nose-tail separation and low yo-yo apex, is not set up in the defender's angular velocity come to deliver his weapons at this instant. However, if the defender takes no action, the attacker will assume the proper position for weapons delivery. The defender, realizing this, knows his selvetion lies in maneuverability - airspeed and angular velocity. Therefore, the defender must relax G when the attacker yo-yo's off and, at the same time, he should maintain his engle of bank. As a result, his nose will drop slightly below the horizon, thus helping him to keep his maneuvering airspeed. Also, as we shall see, it forces the attacker to commit himself. Upon observing the greater turn radius and the nose-down condition, the

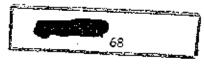


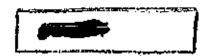


attacker has the option of maintaining his yo-yo apex or committing himself to an attack against the descending defender. It is obvious that the attacker is committed to press his advantage. If not, the defender will increase separation and place the attacker in an undesirable overhead position with a negative delta Mach. Knowing this, the attacker drops his nose and attempts to set up for a missile launch. or 20mm attack. The defender, observing this committment, employs top rudder and back pressure to pull up into the attack. He has approximately two seconds to start this maneuver - the amount of time which the attacker needs to successfully delivery an IR missile or to initiate a 20mm cannon attack. If the defender waits for the committment and counters correctly, the attacker will be placed in a nose-low condition, while the defender has a nose-high attitude. The attacker's airspeed, in respect to the defender, will be increased and his rate of turn will be less. (If the attacker's rate of turn were the same or greater then that of the defender, he would block out the defender and slide in front.) At the same time, since the attacker is approaching the horizontal position and the defender the vertical position, the attacker's radial G, in respect to his total G, is less as compared to the defender's radial G in respect to his total G. Since the attacker's airspeed is greater, his rate of turn is less, and because he has a lower radial G relationship, his radius of turn must be greater (radius of turn = Fighter velocity squared divided by rate of turn). The result is obvious: The attacker will be forced into an overshoot, below and forward of the defender's line of flight. See figure 25. To gain the offensive, the defender need only roll or slide down to the attacker's six-o'clock position. Once again, if the defender has little nose-tail separation, and enough vertical displacement, he should employ the roll in order to achieve an advantage.

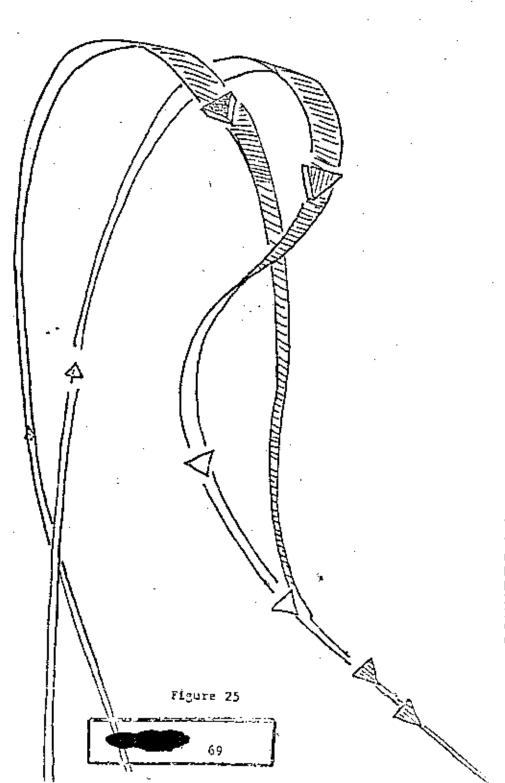
To successfully maneuver against a defender's countering pull-up, the attacker must keep in mind the relationships involved: The pull of one-G gravity causes the attacker's airspeed and turn radius to increase in respect to the defender. Therefore, the attacker's advantage lies not in turn, but in airspeed in respect to the defender. We stated that the purpose of the high-speed yo-yo was to maintain nose-tail separation and that it was acquired by turning through the vertical the defender turns through a plane intersecting the plane of nose-tail separation, along with some lateral separation in the vertical plane. Nose-tail separation prevents a possible reverse by the defender.

In our present situation, the attacker has the same problems of trying to maintain nose-tail separation, however, he can maintain this separation by turning in a plane away from the defender's turn. The attacker merely rolls one quarter away from the defender's line of flight at the instant he observes the defender's rolling pull-up. At the same time, he begins a smooth pull-up behind the defender's line

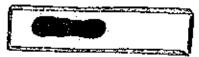




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COUNTERING THE HIGH SPEED YO-YO

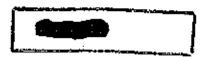


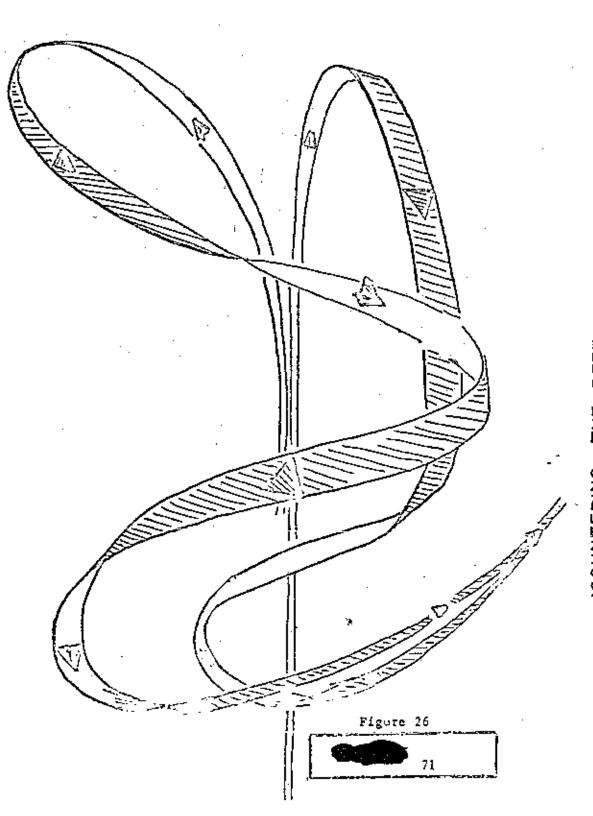
of flight. See figure 26. The attacker plays his pull-up so that he does not overshoot the defender's original altitude. (An overshoot here would be the same as an overshoot in the horizontal plane before executing a high-speed yo-yo). Since the attacker starts from a high position, his airspeed at the bottom of the pull-up will be greater than his opponent's at that same level, with a consequent advantage. If the defender continues his pull-up, the attacker zooms above and rolls behind the defender - the attacker's airspeed advantage pays off. If the defender attampts to dive away, the attacker cuts off through the horizontal plane and moves into the defender's six-o'clock position.

The defender can counter the attacker's one-quarter roll-away. When the attacker is near the bottom of his pull-up, his airspeci is max; while the defender, near the top of the zoom, has minimum sirapsed. The attacker has not only generated mose-tail separation but also lateral separation in the vertical plane. To counter this situation, the defender must rotate his angular velocity cone away from the attacker. In other words, he turns from a nose-high to a nose-low position, through the vertical plane, into the attack. This places the defender in a nose-low, nose-quarter attack, with the defender's airspeed increasing and the attacker's airspeed decreasing. The defender now relaxes G, lights afterburner and dives for separation. Meanwhile, the attacker must turn 1800 through the vertical plane, to acquire a six-o'clock position. During this maneuver, the attacker continues to dissipate airspeed. By the time he completes the maneuver, he is placed in an overhead attack with a negative delta Mach, well outside 20mm cannon range. The defender can easily frustrate a possible missile launch.

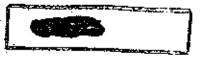
Procedures for the Migh-Spred Yo-Yo

- Attempt to reduce angle-off and stay on the inside of the turn as range diminishes.
- 2. Maintain back-pressure, employ top rudder and roll away from the turn, up through the vertical plane, when you can no longer stay inside your opponent's turn radius. As the pipper slides behind the target you are no longer matching your opponent's turn you must zoom off to prevent an overshoot. In other words, any time it becomes impossible to maintain parallel-fuselage with your opponent, your angle-off will be too great and you must zoom into a high-speed yo-yo.
- 3. Play the zoom so as to maintain nose-tail separation and yet retain a low yo-yo spex. If proper stick and rudder technique is employed, this is easily accomplished.
- 4. Roll, or slide down to your opponent's six-o'clock position. Employ the poll, if you have nose-tell separation, to acquire a six-o'clock advantage.





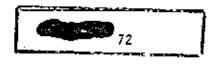
COUNTERING THE DEFENDER'S PULLUP



- 5. Use extreme caution when dropping down to your opponent's six-o'clock position. Do not acquire a steep nose-down attitude, otherwise your opponent may reverse up into you. This is a difficult situation to recover from. However, if it does occur, employ the following procedures.
- 6. Roll one-quarter turn away from your opponent's line of flight, the instant your opponent begins a pull-up, and you recognize a steep nose-low attitude as you approach tracking range. This maneuver will provide nose-tail separation and lateral separation in the vertical plane.
- 7. Initiate a smooth pull-up after the quarter-roll without overshooting your opponent's original altitude, continue the pull-up, turn and zoom toward his six-o'clock position. If your opponent attempts to dive away, cut off in the horizontal plane and slide toward his six-o'clock position.

Procedures for Countaring the High-Speed Yo-Yo

- 1. Play the attack in an attempt to force your opponent to overshoot. This will force him to counter with a yo-yo maneuver, in order to maintain his offensive advantage.
- 2. Determine whether or not the attacker is going high and to the rear. If he has an extremely high rate of closure, he may be forced into extrema altitude separation. If so, employ the dive-away for separation and place the attacker in an overhead attack with a negative delta Mach. If the attacker maintains nose-tail separation, and a low yo-yo apex, employ the procedures outlined below:
- 3. Maintain angle of bank and relax G, as your opponent slides high. This will place you in a slight descent and will allow you to maintain airspeed for future maneuvering potential. At the same time, it will force your opponent to commit himself to a nose-low attack. Continue to maneuver until he does so.
- 4. Perform a hard-rolling reversal with rudder and back pressure up into the attack. This will cause your opponent to overshoot below and forward of your line of flight, or force him to employ the quarter roll-away. If he overshoots below, simply roll or "S" down toward his six-o'clock position. If he employs the quarter roll-away, employ the procedures below.
- 5. Continue to zoom, and turn through the vertical plane down toward your opponent as he crosses your flight path and begins his zoom toward your angular velocity cone.





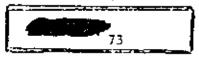
6. Relax G, light afterburner and dive for separation. This forces the attacker to perform a 180° turn through the vertical plane to get back into your six-o'clock position. By the time this is accomplished, you will have placed him out of 20mm cannon range and in an overhead attack with a negative delta Mach.

Barrel-Roll Attack

The high-speed yo-yo appears to be an excellent offensive maneuver to use any time an attacker has a rate of closure and cannot match an opponent's defensive turn. Generally, this is true; however, in a sitwation in Which am attacker approaches a defender at high engle-off (40° or more) and long range (10,000 feet or more) the high speed yo-yo has questionable value. Under these circumstances an attacker would have to yo-yo to an extremely high apex to maintain nosc-tail separation and stay inside his opponent's turn rodius. Naturally, if this occurs, we can expect the defender to immediately dive for separation and airspeed. The attacker is placed in an overhead attack with a negative delta Mach. This means that he must initiate a new attack. Noting this, the defender turns into the attack and generates a high angle-off at long range, and forces the attacker into another yo-yo with high vertical displacement. Once again, the attacker performs a new attack and the process repeats itself. . The result is obvious: If the defender counters each attack successfully, the attacker gains little additional advantage and a stalemate exists. The purpose of the barrel-roll attack is to prevent this stalemate from developing.

Geometric examination of this situation - high angle-off, longrange attack - reveals that the ettacker would not prefer to execute the yo-yo in this manner. Instead, he would appreciate the opportunity to reduce his angle-off and slide into the defender's angular velocity cone, without the defender being able to gain longitudinal separation. In other words, the attacker would like to reduce his velocity, cut off, and turn inside his opponent, then regain his velocity after he diminishes his angle-off, and slide toward his opponent's six-o'clock position. Is this possible? Yes, if we know how to correctly apply the three-dimensional concept of turn and velocity. As previously stated in the introduction to fighter maneuvers, it is possible to reduce turn and velocity by two methods: (1) Through both the vertical and horizontal planes by employing a two-dimensional maneuver (yo-yo) or (2) Mancuver through both the vertical and horizontal planes by employing a three-dimensional maneuver (barrel-roll). Thus far, our emphasis has been on the first method. Now, we will employ both methods to solve our present dilemma - to reduce airspeed and angle-off, then regain airspeed to prevent longitudinal separation.

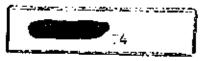
How do we apply this three-dimensional concept? If the attacker attempts to barrel-roll, in the plane of the opponent's turn, he will reduce his vector velocity along the axis of the roll. However, the

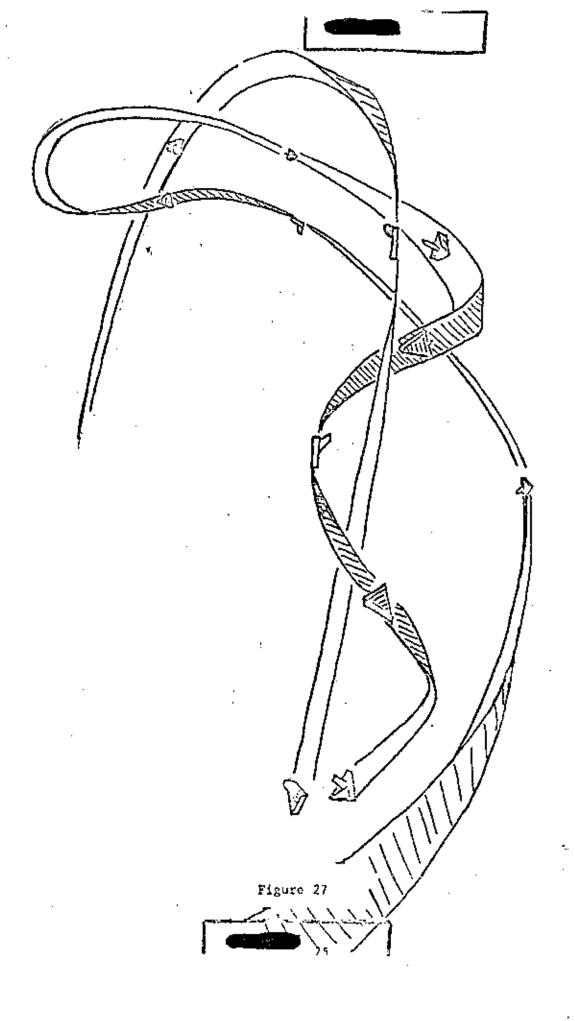




roll will provide a line of flight tangent to his intended turn, which will increase his angle-off and improve the possibility of an overshoot. If the roll is conducted in the vertical plane - combined with a high-speed yo-yo - there is a different result: (1) There is less vertical displacement than in an ordinary yo-yo, because vector velocity along the axis of the woll, in the vertical plane, is diminished, (2) Component velocity, in the plane of the defender's turn, is diminished as a result of the yonyo and the roll, (3) Aircraft velocity is greater, as a result of the lower yo-yo spex and the shortening effect which the roll has on the velocity vector in the plane of the defender's turn. The shortening effect allows the attacker to diminish his rotation engle through the vertical plana. This provides less speed decay, hence greater aircraft velocity, and (4) There will be no overshoot, as a result of the roll, since the roll is not conducted in the place of the defender's turn. Upon further exemination, we can see that if the attacker is able to initiate this yo-yo with a roll, from below his opponent, he increases his opportunity to gain a favorable position. By initiating the maneuver from an insidelow position, the attacker lowers the apex of the maneuver. This provides the defender less opportunity to gain separation. The only problem now is that the attacker must be shid to suply this concept of turn and velocity against his opponent.

To set up the managues, the actacker must dive below and inside his opponent's defensive turn. We assume that the attacker has the range/angle-off relationship specified above, and a dive below will provide the attacker some additional airspand. However, this will not increese his vertical displacement above his opponent, since he can easily kill elaspeed upon his forthcoming rotation through the vertical plane. If the attacker approaches the target from balow and at a high angle-off, he continues to out off, in an attempt to reduce angle-off, until he reaches his pull-up point. The attacker pulls up on the inside of his opponent's defensive turn, then barrel-rolls in a direction away from his opponent's turn. If his opponent's defensive turn is toward the left, he rolls might; if the turn is toward the right, he rolls left. The roll is not a high-G barnel-roll (the attacker is trying to kill vector velocity, not dirigant velocity). As the attacker rolls nose-high through the inversed position, he plays back-pressure and kicks bottom rudder to obtain a nose-low 2700 change of direction. See figure 27. During this postion of the maneuver - from the invested position to the 2,00 point of the roll - the attacker receives the benefit of IG gravity which asplats him in gaining a rapid change of direction toward the defender's six-o'clock position: If the attacker has played the entire managurer - from pull-up through the roll - on the inside of the opposition defensive turn, he will find himself above, at a reduced engle-off and in a position to dive below his opponent's line of flight for a six-o'clock-low position. Longitudinal separation will not be great, for two reasons: (1) Vestor velocity is reduced, but a higher aircrait valently is retained, and, (2) The entire minouver





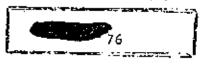
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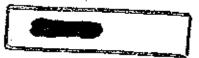


is performed inside the defender's turn radius. The offensive roll-away places the attacker outside of gun range, but inside AIM-9B range at six-o'clock low. Whether the attacker can launch or not, depends on how his opponent plays the defensive turn. If the defender tightens his turn and attempts to counter the maneuver, he will experience high speed decay, his angular velocity will be reduced and the attacker will find it easy to set up for a missile launch. On the other hand, if the defender does not tighten his turn, his airspeed and angular velocity will be greater and the attacker will have to maneuver further, if the defender tightens his turn as the attacker attempts to launch. In any case, we can see that the roll-may provides an effective method by which to reduce angle-off, prevent separation and get into an opponent's angular velocity cone. It is tailored to the performance of the AIM-9B.

To counter the barrel-roll attack there may appear to be certain alternatives such as a high-G roll by the defender when the attacker performs his 270° change of direction, or a pull-up (under the same circumstances). The high-G roll is ineffective because this will cause the defender's line of flight to be tangent to his defensive turn. In addition, his vector velocity will be reduced. As a result, the attacker can easily play his meneuver to slide toward his opponent's six-o'clock position and have less longitudinal separation, since his opponent reduced his vector velocity. The pull-up is ineffective, since the attacker is not committed to a nose-low position by employing bottom rudder. Instead, he may employ top rudder when rolling from the inverted position. At the same time, the defender must roll away from his defensive turn to execute a pull-up. This provides the attacker with sufficient longitudinal separation and time to play his top rudder. Result: The attacker rolls toward his opponent's six-o'clock position, with his opponent framad against blue sky - a perfect set-up for a missile launch. The only effective counter for a properly executed roll-away is a dive for separation and airspaed. The moment the attacker initiates his pull-up, the defender should turn nose-low toward the pull-up, relax G, light afterburner and dive for separation. This forces the attacker, even though he may use the roll-away, to perform a 1800 change of direction in the vertical plane. If the attacker pulls considerable G in acquiring this change of direction, he diminishes airspeed considerably in respect to the defender. If the attacker plays the maneuver with less G, his vertical displacement is greater. No matter which action he employs, he will be placed in an overhead attack with a negative delta Mach.

To maneuver against this counter, an attacker may employ some deception. The purpose of the deception is to prevent the defender from employing the dive for separation. Instead of pulling up inside the defender's turn, from an inside-low position, the attacker will pull-up to the outside of his opponent's turn, thus maintaining nose-tail separation. To the defender, this will appear as an overshoot. Therefore, we can expect him to reverse nose-high, in an effort to seissor the



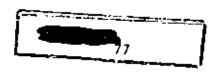


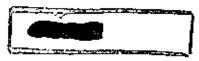
attacker forward. However, if the attacker plays the maneuver properly - overshoot and zoom - this will be impossible. The attacker has a three-fold advantage in terms of airspeed, nose-tail separation, and s high rotation angle in the vertical plane. This means that the attacker may zoom above end behind, but outside his opponent's turn. The defender will be unable to match the attacker's zoom. If the defender reverses (he most likely will) this will place the attacker above, behind and to the inside of his opponent's turn. The attacker need only roll off in a direction away from his opponent's turn. This will reduce vector velocity, provide nose-tail separation and thus allow the attacker to roll down toward his opponent's six-o'clock position. The defender will be in a poor position to counter, since he has diminished airspeed and angular velocity as a result of his turn and nose-high reversal. Should be attempt to pull up into the attacker, the attacker need only employ top rudder on his roll-off toward the defender's six-o'clock position. If the defender dives away, the attacker employs bottom rudder on his roll-off to prevent separation. In either case, the attacker will be in a favorable position to fire the 20mm cannon or launch a missile. More than likely he will be set up for a 20mm cannon attack. If the defender does not react with a reversal, to counter the overshoot and roll-off, but instead dives away for separation, he will place the attacker in an overhead attack with a negative delta Mach. The separation from this barrel-roll attack will be greater than from the one conducted on the inside of the turn. It is difficult to determine which attack is best. However, if the defender's conditioned reflexes are oriented toward a scissors maneuver in the event of an overshoot - the attacker should employ the outside method; if not he should employ the inside method.

The barrel-roll attack, or roll-off maneuver, need not be limited to the conditions specified above. It may be employed at shorter ranges and lower angles-off. The purpose is to reduce rate of closure and angle-off and provide the defender little opportunity to gain separation. As stated earlier, this is an especially good maneuver by which to slide into an opportunity almost a maneuvering the attacker a better opportunity to launch against a maneuvering target.

Procedures for the Barrel-Roll Attack

- Stalk your target and attempt to reduce angle-off as much as possible. If this is impossible, employ the procedures outlined below;
- 2. Dive below and inside your opponent's turn radius, maintaining nose-tail separation throughout the maneuvers. The dive below should be initiated far enough out so the forthcoming zoom may be played inside or outside the defender's turn.

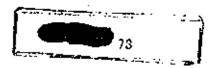


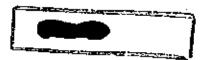


- 3. Pull up and zoom inside your opponent's turn radius if you feel he is not strongly oriented toward the scissors maneuver (sometimes this is difficult to determine).
- 4. Barrel-roll, nose-high, in a direction away from your opponent's turn. If he turns right, barrel-roll left, and vice versa. The roll will reduce vector velocity and the height of the yo-yo apex, while maintaining a higher aircraft velocity.
- 5. Continue the roll and employ bottom rudder as the aircraft comes through the nose-high inverted position. This will provide a 270° change of direction and place you with longitudinal separation, at a reduced angle-off above your opponent, diving toward a six-o clock-low position. The longitudinal separation will be less than that acquired from an ordinary yo-yo.
- 6. Do not employ bottom rudder if your opponent rolls away from the turn and pulls up into the attack. Instead, employ top rudder and continue the roll from the inverted position. This will place you in a nose-high attitude at six-o'clock-low a perfect set-up for e missile launch.
- 7. Pull up and zoom to the outside of your opponent's turn radius if you feel you can sucker him into a turn-raversal. If he reverses, continue with the following procedures.
- 8. Roll in a direction opposite your opponent's turn-reversal. This will reduce your vector velocity and help maintain longitudinal separation.
- 9. Play top or bottom midder, according to whether your opponent pulls up or dives away after the reversal. If he pulls up, employ top rudder. This will allow you to roll nose-high toward a six-o'clock-low position. If he dives away, employ bottom rudder. This will allow you to roll nose-low and prevent your opponent from obtaining extreme longitudinal separation.

Procedures for Countering the Barrel-Roll Manauver

- : 1. Play the attack in an attempt to generate angle-off and prevent your opponent from setting up for a missile launch. If your opponent counters with a dive below and to the inside of your turn radius, continue with the procedures outlined below.
- 2. Turn, nose-low toward the attack, as your opponent initiates his pull-up from an inside-low position. This will increase his angle-off, since you are turning into the plane of attack.





3. Relax G, light afterburner and dive for separation. This will force the attacker to turn 180° in the vertical plane toward your line of flight. During this mencuver, he will be dissipating airspeed while you will be increasing airspeed. As a result, at the end of this 180° turn, he will be placed in an overhead attack with a negative delta Mach, beyound gunfire range and in a poor position to launch a missile.

The Low-Speed Yo-Yo

Until now, our central theme in discussing tactics has been the problem of overshoot. The defender's maneuvers have been predicated upon rate of closure. He needs rate of closure to generate an overshoot in order to nullify an attack and gain an offensive advantage. On the other hand, the attacker attempts to counter rate of closure, by maneuvering through both the vertical and horizontal planes. Discussing these maneuvers - by the attacker and defender - we assumed that the attacker has a definite rate of closure. Now let us investigate an area in factics in which an attacker does not have an initial rate of closure. Assume an attacker is at six-o'clock, outside missile range. How would be gain position to launch a missile or deliver a 20mm cannon attack?

To gain position quickly, the attacker must light afterburner and dive below his opponent's flight path. In other words, trade altitude for airspeed. After reaching an altitude of no more than 10,000 feet below his opponent, he should level out and press the attack from a six-o'clock-low position. The airspeed gained in this maneuver will allow the attacker to quickly close upon his opponent. In addition, it places him in the defender's blind spot, with the possibility that the defender will not maneuver to protect himself. If he does not, the attacker simply closes the distance, executes a pull-up inside missile range and launches.

If he has no missile, the attacker moves in closer and executes a gradual pull-up and positions himself for a gun attack. The entire maneuver depicted here - a dive for airspeed and a pull-up for position - we define as a yo-yo. It may be amployed in a running battle or in a turning fight any time an attacker has insufficient rate of closure.

In a turning fight, an attacker may find himself in a circular tail-chase unable to close upon an opponent. If he tightens his turn, his opponent counters in like manner and the attacker's position remains unchanged. The result is a lufbery maneuver - a stalemate in which the attacker and defender bleed off airopeed and altitude. If the attacker attempts a high-speed yo-yo in an attempt to break the stalemate and gain a more favorable position, he will break the stalemate but will lese rather than gain a more favorable position. To employ the high-speed yo-yo, the attacker must roll away from the circular

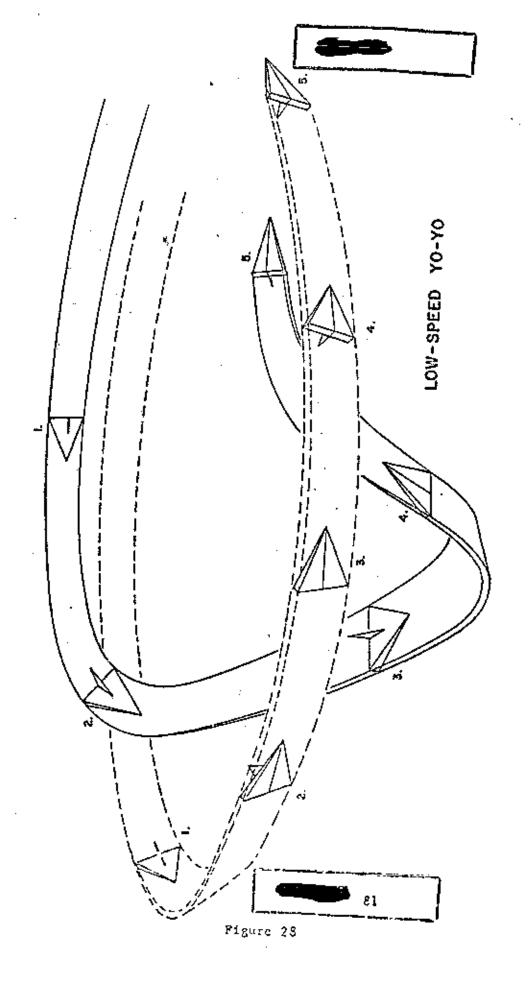


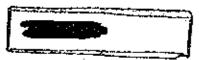


tail-chase and zoom in the vertical plane. The roll-away decreases if turn rate and increases turn radius, whereas the zoom dissipates airspeed and also decreases turn rate. The defender now has an airspeed and rate-of-turn advantage. Result: He moves around the lufbery circle away from the attacker's nose, toward his tail.

To gain a more favorable position, the attacker must be able to cut off and close upon his opponent. The purpose of a low-speed yo-yo is to provide cut-off and rate of closure. To employ the low-speed yo-yo when in a turning fight, the attacker simply maintains his bank and lowers his nose to the inside of the turn (see figure 28). He is now turning through both the vertical and horizontal planes. The pull of gravity increases aircraft velocity, thus increasing turn radius through the vertical and horizontal planes; however, in the horizontal plane the plane of the defender's turn - his turn radius is decreased (in this plane, turn radius is only a component of actual turn). As a result, the attacker turns below and inside his opponent. The attacker's angle-off and sirspeed increase and his distance - in respect to his opponent - decreases along the horizontal plane. To prevent an overshoot, the attacker must roll wings-level, pull up and zoom toward the defender's six-o'clock position. The entire maneuver must be accomplished prior to reaching the defender's line-abreast position. If done correctly, the attacker will find himself at a reduced angle-off and at a diminished range. If he is still not in a lethal position, he need only repeat the process. The attacker gains an advantage in employing this maneuver, because airspeed loss is less than the airspeed lost by the defender. When the attacker dives to the inside, he increases sirspeed and reduces angle of attack. The increased sirspeed provides greater airflow mass to the engine, hence the angine generates more thrust. The decrease in angle of attack reduces induced drag and as a result, in the dive portion of the maneuver, the attacker not only has an airspeed advantage, but also a thrust advantage. On the pull-up to the horizon, angle of attack and induced drag increase. This prevents any further increase in airspeed. However, at this point, the attacker still has a considerable airspeed advantage. In the zoom portion of the maneuver, the pull of one-G gravity starts to diminish airspeed, the loss of airspeed starts to increase angle of attack; however, angle of attack is less than the defender's because of the greater radial G available in the vertical and horizontal plane as compared to the horizontal plane alone. Because of this, the loss of airspeed in a low-speed yo-yo is less than the loss of airspeed in a horizontal turn through the same distance. Therefore, the attacker gains a more favorable position even though he goes through a greater

If the attacker employs afterburner, he will find the maneuver even more effective, even though his opponent may counter in like manner. The afterburner is essentially a ramjet tenden to a turbo engine, therefore, its thrust, like a ramjet, multiplies enominously

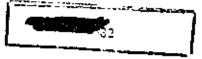




as speed increases. Because of the additional speed thus generated, the attacker need only employ the yo-yo one time in order to gain a favorable position. The afterburner can best be used during the descent and zoom portion of the yo-yo, not during the pull-up to the horizon. If afterburner is used from pull-up to the horizon, the component of afterburner thrust acts in the same direction as the pull of gravity. Unlike max power in a horizontal turn, this causes the attacker to describe a wider are during the pull-up. This may reduce the effectiveness of the maneuver. On the other hand, if considerable inside the defender's turn, employ afterburner throughout the entire meneuver. This will enable the attacker to quickly reduce range and zoom into his opponent's angular velocity cone.

A defender cannot effectively counter a properly-executed low-speed yo-yo by tightening his turn, initiating a reversal, or performing a high-G barrel-roll. If the defender tightens his turn, he dissipates his airspeed rapidly to a point where he reduces his angular velocity and increases his turn radius. The attacker then has no great problem in zooming up toward his opponent's six-o'clock position. The attacker may even play the zoom - out of a low-speed yo-yo - so that he will overshoot his opponent's flight path in the horizontal plane. If the defender reverses, the attacker rolls off in a direction opposite the defender's turn toward his six-o'clock position. If the defender initiates a reversal as the attacker starts into his low-speed yo-yo, the defender will be turning away from the attack, hence rotating his angular velocity cone toward the attacker. The attacker simply pulls up on the inside of the reversal and maneuvers toward his opponent's sixo'clock position. The reversal allows the attacker to reduce more G than is possible against a tight turn, and as a result, his rate of closure increases to enable him to gain a favorable position more rapidly. If the defender executes a high-G roll, out of his turn, he reduces vector velocity and flys tangent to the intended turn, thus permitting the attacker to zoom out of his low-speed yo-yo and quickly secure a six-o'clock position. The defender will be in a poor position to counter, since the roll kills his airspeed and maneuvering potential.

To counter a low-speed yo-yo, the defender must rotate his angular velocity cone away from his opponent. In other words, he must turn into the plane of the attack. From this explanation, an obvious counter-measure appears to be a diving turn the instant an attacker begins his low-speed yo-yo. This rotates the defender into the plane of the attack and cancels a possible low-speed yo-yo. Of course the two antagonists will be forced to the deck rather quickly. If the defender rolls out of the turn his opponent will be positioned at eix-o'clock. Thus the defender receives only a respite from a stalemate situation. We can see from this illustration that a defender must not only rotate his angular velocity cone away but also do it in such a manner as to completely nullify his opponent's low-speed yo-yo. He

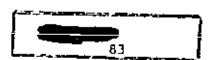


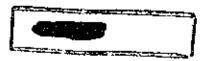


can accomplish this in the following manner: the defender allows the attacker to dive below and inside his turn until a pull-up is begun. At this point the defender is in no immediate danger, since the attacker is diving away from his angular velocity cone. As the attacker begins his pull-up, from a nose-low attitude, the defender rolls away from his turn and zooms in the vertical plane in a banked attitude. By this action, the defender rotates his angular velocity come toward the attacker's line of flight. Observing this, the attacker continues his pull-up in an effort to move toward the defender's six-o'clock-low position. By the time the attacker's mose reaches the horizon on his pullup, the defender will be nose-high in a bank toward the attacker with considerably less airspeed than the attacker. At this point the defender rotates his angular velocity cone away from the attacker by turning, from a nose-high to a nose-low position, through the vertical plane into the attack. This places the defender in a nose-low, nose-quarter attack with the defender's airspeed increasing and the attacker's airspeed decreasing. The defender now plays his action according to the attacker's intentions. If the attacker continues his zoom and turns 180° through the vertical plane, without cutting off, the defender relaxes G, lights afterburner and dives for separation. This places the attacker in an overhead attack with a negative delta Mach. On the other hand, if the attacker cuts off and overshoots his opponent in the vertical plane, the defender may employ a different counter - the vertical rolling scissors.

Procedures for the Low-Speed Yo-Yo

- 1. Dive below and inside your opponent's turn, if you are in a circular tail-chase, and have little or no rate of closure. This maneuver will increase airspeed, diminish your horizontal turning component, and allow you to set up a rate of closure and maneuver inside your opponent's turn.
- 2. Employ efterburner in the descent and in the zoom portions of the maneuver. Do not employ afterburner during the pull-up from the nose-low to a nose-level position. The use of afterburner in the descent and zoom portion of the maneuver increases and helps to maintain rate of closure. When afterburner is employed during the pull-up, a wider arc is described, possibly ruining the effectiveness of the maneuver.
- Do not burble the aircraft, otherwise drag is increased, airspeed is decreased and consequently, zoom capability is diminished.
- 4. Shallow out your turn and begin a pull-up toward your opponent's six-o'clock position. This should be accomplished from an inside-low position before you reach a position line-abreast of your opponent.





- 5. Employ afterburner as your nose comes through the horizon and zoom toward your opponent's six-o'clock position.
- 6. Repeat the low-speed yo-yo if necessary until a launch or firing position is reached.

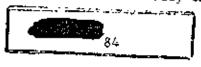
Procedures for Countering the Low-Speed Yo-Yo

- I. Continue to turn and observe your opponent's dive below and to the inside until a pull-up is begun. You are attempting to gain lateral separation in the vertical plane before initiating your countermaneuver.
- 2. Roll away from the turn and zoom in a banked attitude toward your opponent at he begins his pull-up. This will diminish airspeed and rotate your angular velocity come toward your opponent. He will maneuver in an attempt to gain position inside this come at six-o'clock low. As his mose reaches the horizon, in this attempt, maneuver as outlined below.
- 3. Turn, from a nose-high to a nose-low attitude, through the vertical plane into the attack. This will place you in a nose-low, nose-quarter attack with your airspeed increasing. Your attacker will be in a zoom with airspeed decreasing.
- 4. Relax G, light afterburner and dive for separation if your opponent does not cut off and overshoot your flight path. If he attempts to cut off and overshoots your flight path, employ the vortical rolling scissors.

Countering the Overhead Attack with a Negative Delta Mach

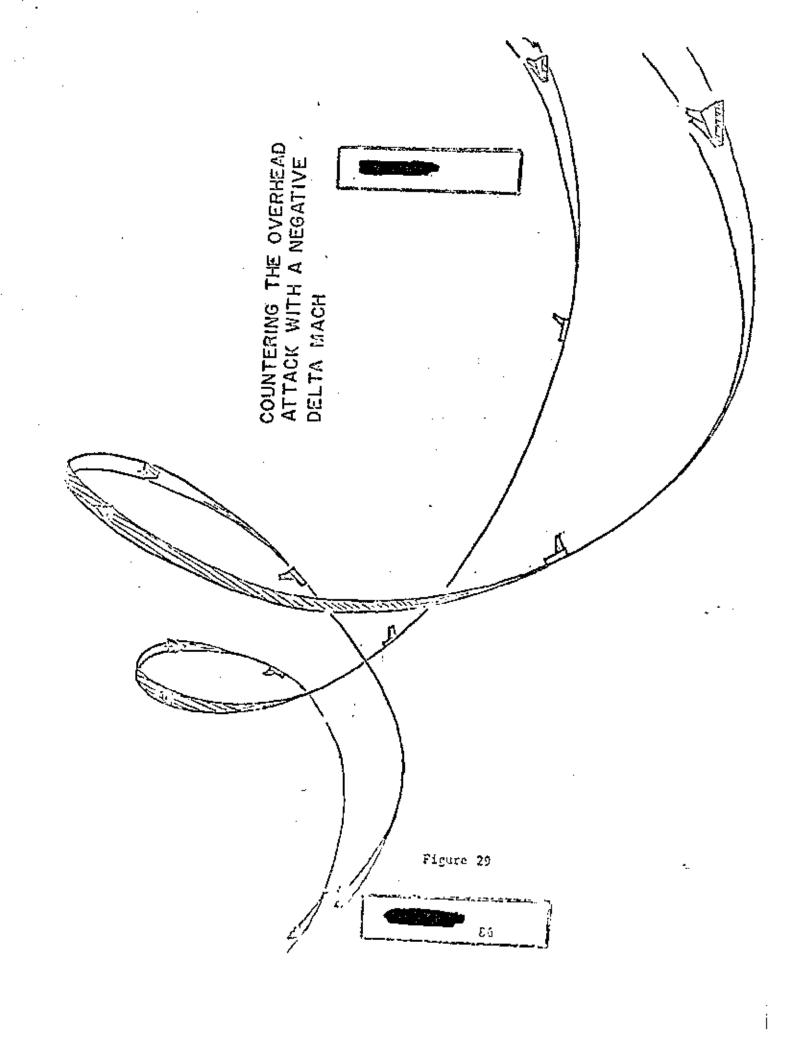
In our discussion of previous maneuvers, we have encountered many situations in which the defender had to dive for separation in an effort to gain maneuvering airspeed and to provide the attacker the worst possible position for a missile attack - an overhead attack with a negative delta Mach. We will now discuss possible counters to this attack.

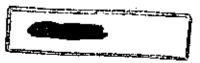
In an overhead attack, with a negative delta Mach, the attacker is in the worst possible position to launch and IR missile. The attacker must not only consider IR background clutter, but the lambda and G limitations of his missile. The lambda limit is especially important because of the attacker's negative rate of closure in respect to the target. If the defender performs any defensive maneuver at all, a low relative missile velocity will be combined with an increasing angle-off. As a result, the defender can easily prevent a successful missile launch. G is significant because the attacker must maneuver against one-G gravity. This means he will easily exceed the two-G lounch



limitation and/or the angle-of-attack limitation against a maneuvering defender. To elude an attacker, the defender need only rotate his angular velocity cone away from the attacker's line of flight. In an overhead attack with a negative delta Mach, he may accomplish this in two ways: (1) Pull up to the horizon, wings level, and perform a defensive turn left or right (the direction dependent upon whether the attacker is high to the left or high to the right). Let's discuss each alternative in detail. First the pull-up and zoom in the vertical plane.

The moment the defender observes his opponent lining up for a possible missile shor, he pulls up and zooms in the vertical plane. During the pull-up - from nose-low to nose-level - he does not employ afterburner. As his nose hits the horizon, he lights afterburner and zooms in the vertical plane. The attacker, faced with this counter, has one of two alternatives: (1) Cut off, in an attempt to secure a six-o'clocklow position as the defender zooms through the vertical plane, or, (2) Do not out off but fly the same relative flight path as the defender. In all probability, the attacker will be entired into a cut-off, because he thinks the cut-off will quickly position him for a missile launch. This, however, is what the defender is actually hoping and waiting for. If the attacker cuts off, he will not take advantage of the pull of gravity to build up his editare to themselve, at the bottom of his pullout, he will generate a lower airspeed than did the defender when the defender was at the bottom of his pull-out. The cut-off and lower airspeed force the attacker to recute his rotation angle in the vertical plane in respect to the defender. This means that he will be unable to secure a six-ofolouk position. Instead, he will be forced to accept a smaller rotation angle, hence a flight path overshoot in the vertical plane (see figure 29). Mesnwhile, the defender with his airspeed margin, can pull toward or past the vertical and execute a roll-off - not a loop - down toward the attacker's six-o'clock position. To counter, the attacker will attempt to complete his zoom and roll-off; however, the attacked will lose out because of his initial lower altapest on his first cut-off and his smaller rotation angle. As a result, the defender will quickly gain an advantage and move toward the attacker's six-o'clock position. If the attacker had not cut off on the initial pull-up and zoom, but had pulled up and zoomed through the same are as the defender, he would not have lost his advantage. As the defender reached the near vertical, the attacker would be near six-o'clock. This means the defender would be unable to successfully woll off and gain a six-o'clock advantage, since he would not have an overshoot in the vertical plane. If he did, the attacker would simply follow and gain a more favorable position. To prevent this, the defender must turn 1909 through the vertical place and once atain relax G and dive for separation. The attacker, noting this, will be faced with the choice of attempting to cut-off or zoon past the defender through the same turning point to complete a 180° change of direction toward the defender's six-o'clock position. If the attacker attempts to out off and overshoots his

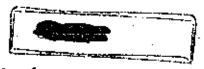




opponent in the vertical plane, the defender may employ the vertical rolling scissors as a counter. On the other hand, if the attacker does not cut off, the overhead attack with a negative delta Mach will be tepeated once again. To counter this second attempt, the defender may execute the second alternative - a pull-up to the horizon and a defensive turn, left or right. If the attacker is to the rear and off to the left, the defender will turn left, and vice versa. If the attacker presses the attack, in a curved plane intercepting the defender's turn, he will describe a nose-low spiral. As range diminishes, the attacker's airspeed and G will build up. The defender, observing his opponent's attack, will tighten up his defensive turn as the attacker's range diminishes. If the attack is continued, the nose-low spiral forces the attacker into an overshoot below the defender. The result is obvious: The defender simply rolls off and maneuvers toward the attacker's six-o'clock position. If the attacker attempts to yo-yo out of this nose-low spiral - before overshooting below his opponent's flight path - he must roll wings-level in order to pull up and zoom in the vertical plane. This maneuver provides nose-tail separation for the attacker; however, it also provides lateral separation for the defender. In this instance, the defender has taken the advantage. After rolling wings-level the attacker has a nose-low attitude while the defender has a nose-level attitude. This means that the attacker must pull from this attitude to noselevel before he can zoom in the vertical plane. During the process, the attacker increases his horizontal velocity component. This causes him to overshoot the defender's flight path before he can execute his zoom. If, during the pull-up and zoom by the attacker, the defender counters with a nose-high reversal, he will diminish his horizontal component. The result is obvious: The attacker is forced out front by his pull-up and zoom. The defender will be in position, at six-

Procedures for Countering the Overhead Attack with a Negative Delta

- 1. Determine if an attacker is in position to execute an overhead attack with a negative delta Mach. This can be accomplished by observing the attacker's previous maneuvers and his present relative position. If he is in a proper position, employ the following procedures.
- Pull up from a nose-low attitude and zoom in the vertical plane (wings level). This should be accomplished the moment the defender observes his opponent flying up for a possible missile shot.
- 3. Employ afterburner during the dive and zoom portions of the maneuver. Do not employ afterburner during the pull-up from mose-low to mose-level. Use of the afterburner during the dive and zoom portions of the maneuver and not during the pull-up allows the defender



to generate sufficient angular velocity and, at the same time, maintain a substantial zoom capability.

- 4. Observe and determine if your opponent attempts a cut-off in an effort to secure advantage. If he does, ha will not take advantage of the force of gravity to build up his airspeed. Therefore, in the bottom of his pull-out, he will have a lower airspeed, hence a lower zoom potential as well as a reduced rotation angle.
- 5. Roll off, as you approach the vertical, and meneuver down to-ward your opponent's six-o'clock position. This should be accomplished as your opponent starts in the zoom portion of his maneuver. This will prevent him from getting near your six-o'clock position. At the same time, it ellows you to gain toward his six-o'clock position.
- 6. Repeat the process. This means that you will dive toward the attacker's six-o'clock position from your roll-off. This will place you at the bottom half of the maneuver. Your attacker, attempting to complete his zoom, will roll off toward your six-o'clock position. However, you will gain on him because of his initial lower airspeed when he performs his first cut-off.
- 7. Do not attempt the roll-off if the attacker does not cut off on the initial manauver. Instead, turn 180° to the vertical plane, relax G and dive for separation. If the attacker does not cut off, he will be near your six-o'clock position as you reach the near-vertical. To provide him little advantage, you must turn 180° into the attack, dive for separation, and once again place him in an overhead attack with a negative delta Mach.
- 8. Determine, once again, when the attacker is in an overhead attack with a negative delta Mach, then get ready to employ the second alternative.
- 9. Pull up to the horizon with wings level, then perform a defensive turn left or right (the direction is dependent upon whether the attack is high to the left or high to the right). If the attacker counters the first alternative, he will meet the second in an effort to gain an advantage.
- 10. Continue the turn and observe the attacker. If he presses the attack in a curved plane intercepting your turn, proceed as follows:
- 11. Tighten up the turn, as the attacker's range diminishes, and attempt to force him below your line of flight, or attempt to force him into a youyo cut to the side. If he continues the attack, he will be forced into an overshoot below you.





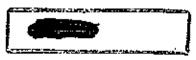
- 12. Roll off and maneuver toward the attacker's six-o'clock-low position if the attacker continues the attack and is forced into an overshoot below you. If he yo-yo's out to the side, employ the following procedures.
- 13. Reverse nose-high to force the attacker below and out front. Since the attacker must pull up before he can zoom, his horizontal velocity will carry him below and forward.
- 14. Roll off and maneuver toward the attacker's six-o'clock-low position as he completes his pull-up and proceeds in the zoom portion of his maneuver.

Maneuvering from An Overhead Attack with a Megative Delta Mach

You will recall, from our previous discussions of the overhead attack with a negative delta Mach, that an attacker may expect two possible counters to his attack: (1) A pull-up from a nose-low attitude, followed by a zoom in the vertical plane, or (2) A pull-up to the horizon, wings level, followed by a defensive turn left or right. Our purpose in discussing the overhead attack with a negative delta Mach is to point out maneuvers which can be used against either one of these counters.

To-maneuver against the first alternative - pull-up from a nose-low attitude with a zoom in the vertical plane - we stated that the attacker should not cut off and pull-up and zoom. Instead, he should fly the same relative flight path as the defender. By doing this, the attacker would force the defender to turn 1800 in the vertical plane in an attempt to gain longitudinal separation. We can see, by geometrically examining this situation, that the attacker has an apparent choice of either cutting off his opponent in the vertical plane, or zooming past the defender through the same turning point to complete a 180° change of direction toward the defender's six-o'clock position. If the attacker attempts to cut off and over-shoots his opponent's descending flight path in the vertical plane, he can expect the defender to counter with the vertical rolling scissors. This will cost him his offensive advantage. On the other hand, if he does not cut off, the overhead attack with a negative delta Mach will be repeated once again, and he will gain little additional advantage. To prevent either situation from occurring, the attacker need only employ a barrel-roll (roll-gway) in the vertical plane, as he starts to move past the descending defender. This will reduce the apex of his zoom, because his vector velocity (along the axis of the roll) in the vertical plane is disinished. As a result, the attacker will roll away through a 180° change of direction to position himself at his opponent's six-o clock-lew_position, in the vertical plane, with much less longitudinal separation. If the defender repeats the pull-up and zoom, followed by a 1800 turn in



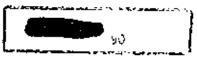


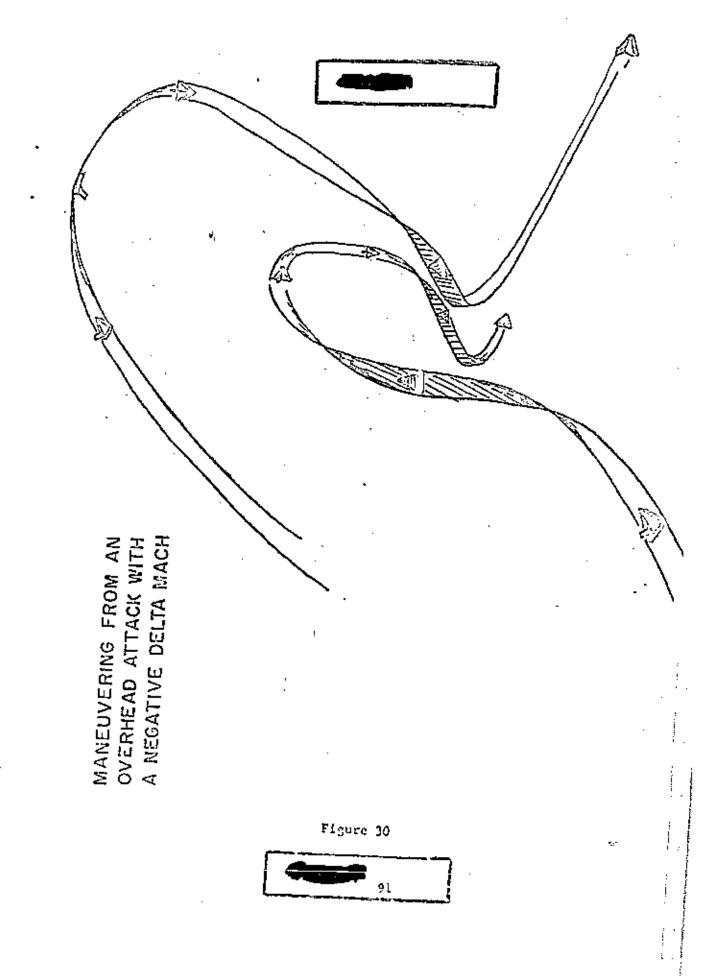
the vertical place, the attacker need only repeat the process to gain an even more favorable position. He may then set up for a missile or 20mm cannon attack.

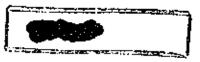
To counter this roll-away, the defender need only add back-pressure and roll toward the roll-away, or dive for whatever longitudinal separation ha can get to amploy his second alternative. If the defender rolls toward the roll-away, this will place the attacker at a high angle-off in the vertical plane, as shown in figure 30. To maneuver out of this position, the attacker must roll 1800 toward the defender's flight path. Meanshile, the defender can relax G, dive for separation and attempt his second alternative.

To maneuver against the second siternative - a pull-up to the horizon, wings-level, with a defensive turn left or right - the attacker must not launch an overhead attack in a curved plane egainst the rim of the defender's howirontal turn. This means that if the attack is pressed, the attacker has the option of descending outside his opponent's turning circle or descending inside the turning circle. If the attacker descends outside his opponent's turning circle, his rate of turn will be less than the defender's. This mains the defender will be turning away from the autacker's mose, toward his tall, as the attacker approaches the defender's line of flight. As a result, the defender will maneuver toward the attacker's simer'elock position. On the other hand, if the attacker descends incide the turning circle, he is not committed to generate a turn wate less and a turn radius greater than his opponent, as would be the case if he initiated a pursuit curve attack, in a curved plane (either intemporing the defender's horizontal turn or descending outside his turning circle). By descending inside the horizontal circle, the stimiler describes a nose-law spirel, in which his rate of turn, along the horizontal exis, is governed by his spiral or roll rate along the vactical axis. His radius of turn along the horizontal axis is governed by the slope of his descending spiral. If the attacker increases his roll wate (in the spiral) and steepens the spiral, he increases his borizontal turn rate and decreases his horizontal turn radius. In effect, the attacker will be pimouetting down the exls of the defendan's hardsonted turn. This, of course, will cause the attacker to build up excessive velocity for his forthcoming maneuver unless he reduces power. As the attacker pulls well inside and below the defendag's turning circle, he rolls out of the spiral and executes a pull-up and zoon toward the defender's six-p'clock position. (In other words, he employs a variation of the low-speed yo-yo.) If the actionar's simple of is our relive and it appears that the resulting zoom may forme him two high and/or to the outside of the defender's turning chrois, the enterker simply employs the benrel-roll attack in an effort to secure a leanth or fining position.

To counter the invisively reverses (the low-speed yeary) or the barral-yold attack) out of the overtied attack with a regutive delta



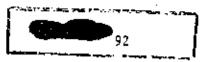


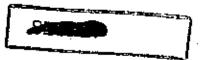


Mach, the defender need only employ the counters suggested for a low-speed yo-yo and/or for the barrel-roll attack.

Procedures for Maneuvering from an Overhead Attack with a Magative Delta Mach

- 1. Observe your opponent and determine if he employs alternative 1 a pull-up from a nose-low attitude and a zoom in the vertical plane or alternative 2 a pull-up to the horizon, wings-level, and a defensive turn left or right. If he employs the first alternative, use the following procedures.
- 2. Do not cut off as your opponent begins his pull-up for a zoom in the vertical plane. A cut-off now will provide you a lower airspeed and a smaller rotation angle for your forthcoming zoom.
- 3. Dive A/B on and initiate a pull-up and zoom through the same are which the defender described. This technique will enable you to generate a high rotation angle in your zoom, hence, prevent a flight-path overshoot, in the vertical plane.
- 4. Determine if your opponent counters with a roll-off or a 180° turn through the vertical plane in an effort to maneuver you out of his six-o'clock position. If he employs the roll-off, simply roll with him and maneuver toward his six-o'clock position. If he employs a 180° turn through the vertical plane in an effort to gain separation, employ the following procedures.
- 5. Initiate a barrel-roll (roll-away) as you begin to zoom past your descending opponent. A roll-away will reduce your vector velocity in the vertical plane; hence, provide your opponent less longitudinal separation.
- 6. Complete the barrel-roll (roll-away) and maneuver toward your opponent's six-o'clock position in the vertical plane. Your opponent will now either repeat the pull-up and zoom or proceed to his second alternative. If he repeats his previous maneuver, simply repeat your roll-off and gain position for a missile or 20mm cannon shot. If he employs the second alternative, use the following procedures.
- 7. Do not press the attack in a curved plane intercepting the rim of the defender's turn. This will force you to either overshoot below your opponent or to yo-yo out to the side in a nose-lew attitude. In either case, he will gain an advantage (see section on countering the overhead attack with a negative delta Mach).
- 8. Spiral inside your opponent's horizontal turn to match his turn and to cut him off. This may be accomplished by adjusting your wrate of spiral and the alone of the spiral.





- 9. Continue the spiral, inside your opponent's turn, until you start to move below and inside his line of flight.
- 10. Roll wings-level, pull up inside your opponent's turn and zoom toward his six-o'clock position. If you have excess airspeed or are not spiraling well inside your opponent's horizontal turn, you may be forced to pull up and zoom outside his turning circle. In this case, employ the following procedures.
- 11. Zoom outside your opponent's horizontal turning circle if you are unable to complete your pull-up inside his horizontal turn radius then turn back noward him if he continues to turn or attempts to dive away.
- 12. Zoom to the outside and barrel-roll (roll-away) toward your opponent's six-o'clock position, if he attempts a reversal to counter your zoom to the outside.

The Vertical Rolling Scissors

The vertical rolling soldsors is what the name implies - a defensive, descending, rolling maneuver in the vertical plane. The purpose of this maneuver is to gain an offensive advantage if an opponent overshoots a defender's flight path, and slides through his angular velocity cone while descending in the vertical plane. See figure 31. The following situations may be used to set the stage for employing the maneuver: (1) At high altitude, when the defender has a high Mach with a low indicated airspeed. In this case, the defender will be forced to perform a descending defensive turn to maintain future maneuvering potential. If the attacker with a fair rate of closure, thinks that his opponent is attempting to gain separation, he may cut off in an effort to prevent him from doing so. With his higher airspeed, his radius of turn during the cut-off will be greater than the defender's. As a result, he can be easily forced to overshoot the defender's descending flight path. (2) In a zoom-managurer in which the attacker is attempting to approach a zooming defender's six-o'clock position. The defender, observing the attacker's position, uses the pull of gravity and executes a 1800 turn through the vertical plane in an effort to gain separation and thus place the attacker in an overhead attack with a negative delta Mach. In an effort to prevent this, the attacker cuts off. During the cutoff, his radius of turn is greater than the defender's because of this higher airspeed, and as a result, he overshoots the defender's descending flight path. (3) A six-o'clock-low missile attack, in which an attacker is approaching his pull-up point for launch. The defender, observing the attacker, may execute one of two maneuvers: An immediate defensive turn down into the attack, or a pull-up and zoom followed by a 1800 turn, in the vertical plane, down into the zooming attacker (this is the same procedure used as a counter to the low-speed yo-yo). In either of those cases, if the attacker attempts a substantial cut-off he can be forced to overthook his opposent's descending flight path.

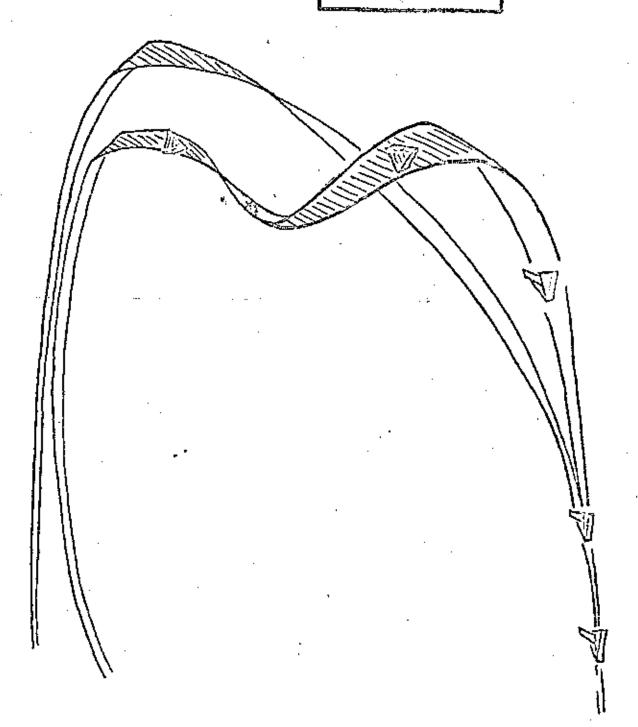
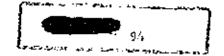
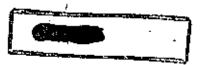


Figure 31

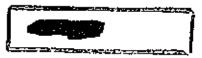




With the stage set, we can now discuss the mechanics of the vertical rolling scissors. Let's essume that we have a defender zooming in the vertical plane, with an attacker initiating a pull-up in an effort to maneuver toward the zooming defender's six-o'clock position. The defender, observing his opponent's position, turns 180° through the vertical plane, down into the attack in an apparent attempt to gain separation. Observing this maneuver, the attacker decides he can either cut off, or zoom and turn 1800 through the defender's turning circle. Since he knows that a turn through the defender's turning circle willplace him in an overhead attack with a negative delta Mach, he elects to cut-off. Observing the cut-off, the defender knows that the attacker will be performing his 1800 turn through the vertical plane at a higher sirspeed. Therefore, the attacker's turn radius will be greater; hence, he will overshoot the defender's descending flight path. Understanding this, the defender reduces power to slow his rate of descent (he may deceive the attacker in this power reduction by momentarily lighting afterburner, then reducing power, to make it more apparent that the defender is trying to dive for separation) then waits until the attacker overshoots his flight path and is committed to a nose-low attitude. At this instant, the defender comes in with back pressure and reverse-rolls into the overshooting attacker. This will place the defender below the attacker and 180° out of phase, with a less nose-low attitude; hence, a lower vector velocity along the vertical axis. The attacker, noting that he is out of phase, and is descending more rapidly than the defender, will attempt to roll. 180° toward the defender's descending flight path. Observing the attacker's action, the defender rolls in the same direction. This prevents the attacker from flying into his opponent's six-o'clock position. At the same time, it prevents him from reducing his nose-low attitude. As a result, the attacker, with his higher vertical vector velocity, has rolled 1800 out of phase, down and below the defender. The defender now has the advantage and he need only roll into the attacker's six-o'clock position.

To counter the vertical rolling scissors, a zooming attacker should not attempt to cut off a descending defender when he has a substantial airspeed adventage. Instead, he should roll away or barrel-roll to reduce his ascending vertical vector velocity, hence his yo-yo apex. In an effort to prevent the defender from gaining longitudinal separation, the attacker need only initiate his roll-away as he starts to ascend past the diving defender. This will allow him to complete his the diving defender. This will allow him to complete his tion him at the diving defender's six-o'clock position with less longitudinal separation and less negative rate of closure. To managiver for a launch or firing position, the attacker need only managiver against the attacker moves in for the kill.



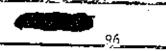


Procedures for the Vertical Rolling Scissors

- 1. Observe the attacker's position. If he is in a six-o'clock-low position, perform the following procedures.
- 2. Pull up and zoom in the vertical plane, or perform an immediate descending defensive turn. If your opponent has not set up a zoom for a launch or firing position, you may employ the pull-up and zoom. If he has, immediately employ the descending defensive turn.
- 3. Turn 480° through the vertical plane, if you zoom, or continue the dive if forced to perform a descending defensive turn.
- 4. Observe your opponent to determine whether or not he will cut off. If he cuts off, employ the following procedures.
 - 5. Reduce power to slow rate of descent.
- 6. Reverse-rell, toward your opponent, when you observe his over-shoot and nose-low committment. A reverse-roll should be accomplished with back-pressure and rudder (high-angle-of-attack maneuver) to reduce your nose-low attitude and your vertical vector velocity.
- 7. Do not allow your opponent to roll toward your flight path keep him 180° out of phase. To accomplish this, roll in the same direction as your opponent if he attempts to acquire your six-o'clock position.
- 8. Continue this rolling maneuver, with your opponent out of phase, until he rolls down and below you. He will be forced into this position because his vertical vector velocity is greater than yours.
- 9. Roll into your opponent's six-o'clock position and maneuver for the kill.

Procedures for Countering the Vertical Rolling Scissors

- i. Do not attempt to cut off as a zooming attacker against a descending defender if you have a substantial airspeed advantage. Under these conditions, a cut-off will force you to overshoot your opponent's descending flight path.
- 2. Roll away or barral-roll as you move vertically past your descending opponent. This maneuver will reduce your zooming vector velocity, hence vertical displacement, in your zoom.
- 3. Continue the roll-away to acquire a 180° change of direction and a six-o'clock-low position against your diving opponent. This prevents your opponent from gaining a considerable longitudinal separation and at the same time reduces your negative rate of closure.





4. Maneuver against any forthcoming counter thrown at you by your opponent.

The High-G Barrel-Roll

There may come a time, in a tactical situation, in which you find that you can nullify a missile attack, but have less success in countering a follow-up 20mm cannon attack. You will recall that a defender can frustrate a missile attack by exceeding the missile's lambda and/or G-capabilities. The maneuvers needed to accomplish this are not too demanding, providing the defender has visual contact with the attacker. On the other hand, a much higher degree of skill - in respect to mansuvering - is needed to counter an aggressive, skillfully-executed follow-up gun attack. Under these circumstances even the most proficient defender may find himself in a serious defensive position, with an attacker at six-o'clock inside gun firing range. To get out of this situation, any defender knows he must force the attacker to overshook his flight path. In other words, he must rotate his angular velocity cone in such a manner as to acquire lateral separation. Turn and velocity, married to the pull of gravity, determine his field of manauver, and his ability to rotate his angular velocity cone. He must employ these factors in proper perspective to gain an overshoot. In this situation, this means that the defender must reduce his turn and velocity more quickly than his opponent if he is to force his opponent out of his six-o'clock position. From our previous discussions, it is obvious that a barrel-roll type maneuver offers the best opportunity to quickly change direction and reduce vector velocity. In this case, since the attacker is at six-o'clock inside gun firing range, the defender must perform a max-performance or a high-G barrel-roll to prevent his opponent from matching his change of direction and reduction of vector velocity. Before initiating the maneuver, his only remaining problem is to determine in which direction the high-G berrel-roll should be executed. To answer this, let's assume that the defender is in a defensive turn with an attacker at six-o'clock under the conditions

In an attempt to force the attacker to overshoot, the defender can either execute a barrel-roll over the top or a barrel-roll underneath out of his defensive turn. If the attacker is at high speed - 300 knots or more in the F-100 - and he performs a high-G barrel-roll underneath, the pull of gravity will act in the same direction as his thrust vector. This means that he will experience considerable difficulty in reducing his vector velocity more quickly than his opponent. On the other hand, if he performs a high-G barrel-roll over the top, his thrust vector acts in a direction opposite the pull of gravity. This means that he will reduce his vector velocity much more rapidly in respect to his opponent. To illustrate both situations: If the defender rolls underneath, he must execute the maneuver first, since the attacker is maneuvering in respect to him. This means that the pull of gravity will act in the second direction as the defender's thrust



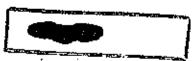
and velocity, before it acts on the attacker. As a result, the defender will experience difficulty in reducing his vector valocity more rapidly than his opponent. On the other hand, if the defender rolls over the top, once again he must execute the manager first, since the attacker is maneuvering in respect to him. In this case, the defender can reduce his vector velocity more rapidly than his opponent since the pull of gravity acts against his thrust and velocity, before it acts against the attacker's thrust and velocity. It is obvious from this discussion that if a defender, at high speed in a defensive turn, has an attacker at six-o'clock inside gun firing range, he should execute the high-G barrel-roll over the top, rather than underneath, in order to gain an overshoot.

If a defender does not have the necessary speed to execute the high-G roll over the top, he should not attempt to do so, because the high angle of attack required to successfully accomplish the meneuver and the pull of gravity will cause his speed to decay very rapidly. If the defender attempts to roll over the top, this means that he will stall out and be unable to complete the maneuver, and the attacker will set up at a sixo'clock position for an easy kill. To prevent this, the defender with insufficient speed to execute a roll over the top, should perform a high-G roll underneath (in the F-190, this maneuver should be initiated with an airspeed of 250 knots or less). In this situation, a defender needs the pull of gravity to successfully complete the maneuver. He will be maneuvering with a high angle of attack. The induced drag generated by this angle of attack will provide a deceleration greater than the acceleration generated by the pull of gravity. Hence, if the defender executes a high-G roll underneath, he can still change direction and reduce velocity more rapidly than his opponent. Why? Eccause the attacker must still maneuver in respect to the defender. The attacker's rate of turn and vector velocity are dependent upon his angle of attack, which, in turn, is dependent upon his rate of turn, which is dependent upon the defender's velocity, angle-off and range (w = Vt x Sin3).

Now that we understand the need for the high-G barrel-roll - both over the top and undermeath - and when it should be employed, let's discuss the mechanics of each maneuver.

The High-G Barrel-Roll over the Top

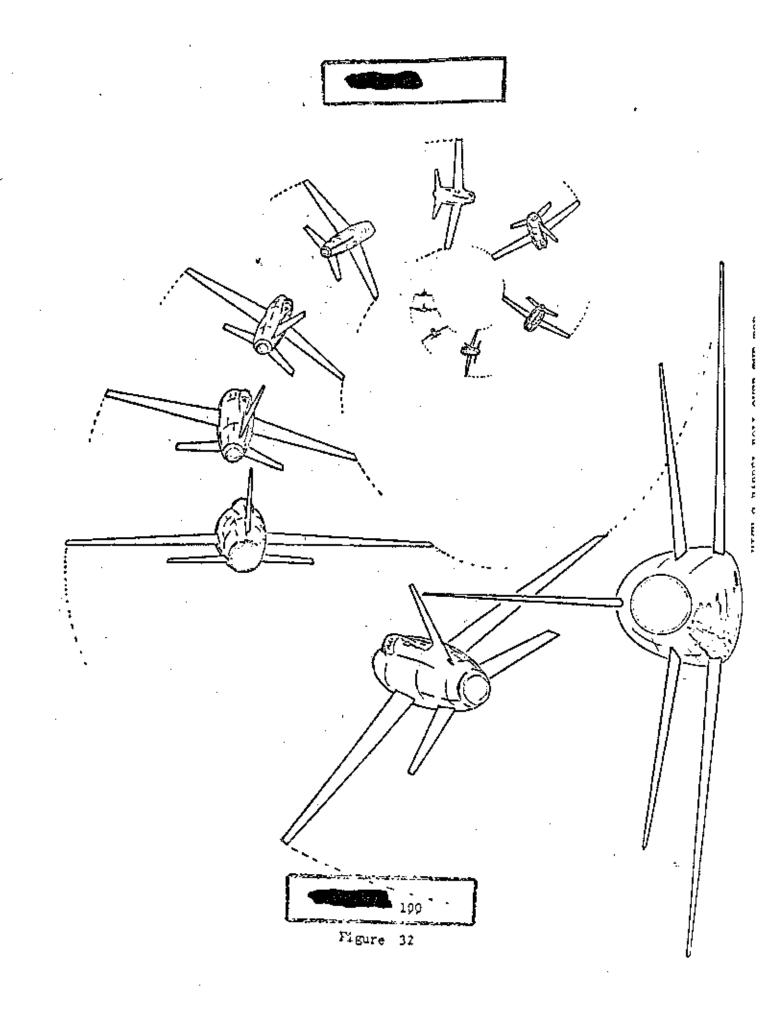
As indicated above, the high-G barrel-roll over the top is designed for use against an attacker at six-o'clock inside gun firing range, when the defender is in a defensive turn and is unable to shake the attacker. More specifically, the attacker should be in fairly close - a range of around 1500 feet on less. If the attacker is at a range much greater than this, the high-G barrel-roll, because of its rapid reduction of the delender's velocity, will only serve to bring him closer toward the defender's six-o'clock position. In other words, this maneuver should not be employed at the longer gun firing ranges or as a defense



against a missile attack. If so, the attacker will simply play the maneuver to reduce longitudinal separation to move into position for a kill. The defender will be in a poor position to counter, since he will have killed all his maneuvering velocity.

With these conditions in mind, the moment the defender realizes he is unable to shake his opponent, he should start to execute the roll (see figure 32). He should not delay, otherwise the attacker may make the kill. To execute the maneuver properly, a defender should maintain back-pressure and start his roll over the top without releasing any G. This means that he must exercise proper rudder and alleron control; otherwise adverse yaw will prevent him from performing the meneuver (some aileron may be required during the start of the roll, however, as the roll progresses, his angle of attack increases and more ruider will be needed). As the defender comes through the inverted position, he should maintain back-pressure and increase his roll rate. If he fails to maintain back-pressure, he will not reduce vector velocity rapidly enough, and will not force his opponent around the outside of the roll. If he fails to increase his roll rate, he will not successfully complete it, since rapid sirpseed decay is reducing his maneuvering potential. As the defender reaches the 270° point - the opposite side of the roll - he should play top rudder to prevent dish-out, and visually ascertain the attacker's position. If, in an effort to secure a kill, the attacker has followed the defender around the roll, he will be forced outside the defender's roll. This means that at the 270° point he will be high, toward the rear and outside the roll (if the attacker has not reduced very much of his velocity during the roll, he will simply be high and to the outside). If, while the attacker is in this position the defender continues his roll-out - holding top rudder to maintain a nose-high attitude - it forces the attacker to slide below and forward in an obvious overshoot. The defender then simply increases his nose-up attitude and rolls or S's toward the attacker's six-o'clock position.

To counter the high-G roll, the attacker may attempt to yo-yo out the top of the roll of reverse-roll out of the top in an effort to secure a six-o'clock position. If the attacker yo-yo's out the top, the intent is obvious - he is attempting to reduce his vector velocity along the axis of the roll by yo-yoing in the vertical plane. In this way he can maintain a six-o'clock-high position after the defender completes the roll. If the attacker reverse-rolls, he will roll through a wider are in the opposite direction. If he maintains back pressure while doing this, he can reduce vector velocity along the axis of the defender's roll more rapidly than the defender. As a result, upon completion of the roll by the defender, the attacker will be at six-o'clock. To maneuver against either of these counters, the defender must ascertain the attacker's position as he approaches the 2700 point in his roll. He will be unable to determine the attacker's position prior to this, since the yo-yo out, or the roverse-roll, places the

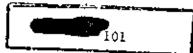




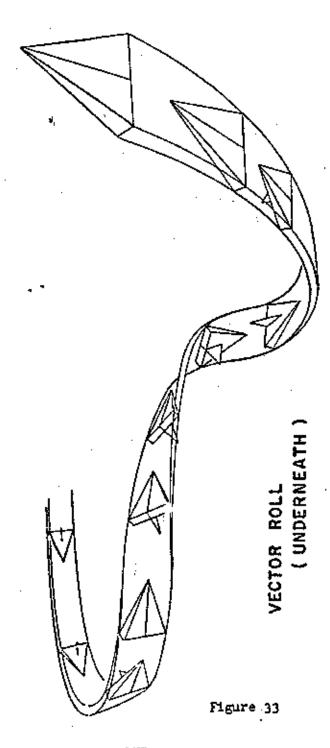
attacker in the defender's blind spot - toward the underside of his sircraft. At the 2700 point, if the defender notes the attacker's position as being toward the rear, at the top of his canopy (by "top of the canopy", we mean that the attacker will be in the horizontal plane when the defender is at the 270° point of his roll) the attacker has performed a reverse roll. If the attacker is in this position, the defender does not complete the roll. Instead, he performs a horizontal turn into the attacker and forces him to overshoot, and dives for separation to gain airspeed and place the attacker in an overhead attack with a negative delta Mach (the defender does not attempt a scissors, since he does not have the airspeed after performing the high-G roll). At the 2700 point, if the defender observes the attacker to be high and to the rear (off the left side of the canopy in a high-G roll to the left, and off the right side of the canopy in a high-G roll to the right by the defender). The defender turns 1800 through the vertical plane, under the attacker, relaxes G and dives for separation. To follow, the attacker must run out of his nose-high yo-yo toward the diving defender's six-o'clock position. This allows the defender to gain lateral separation and places the attacker in an overhead attack with a negative delta Mach.

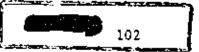
The High-G Roll Underneath

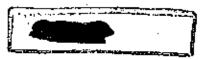
In discussing the high-G roll underneath, let's assume that we have a defender in a defensive turn with an attacker at six-o'clock inside gun firing range. If the defender does not have the necessary airspeed to execute a high-G roll over the top, he will be committed to a high-G roll undermeath. In the F-100, this means that if the defender's airspeed has dropped below 300 knots, he should not attempt the high-G roll over the top. However, before executing the roll underneath, he should maintain G, and allow his speed to dissipate to 250 knots or less. With these conditions prevailing, the defender should immediately start the high-G roll underneath in an effort to shake his attacker. He should not delay, otherwise he will experience considerable speed decay, and will encounter considerable difficulty in executing the maneuver. To execute the roll underneath, the defender maintains back pressure, employs rudder in the direction of the roll - bottom rudder all the way around the roll. If done properly, the maneuver will describe a barrel-roll underneath. To the attacker, just after the maneuver has started, it will appear as a split-S. This illusion is created by the high angle of attack generated in performing the maneuver (this deception will cause the attacker to cut off in an effort to counter his opponent's apparent dive for separation. The cut-off will place the attacker in a steep nose-down attitude). As the defender rolls past the inverted, near-vertical position, to the completion of the managurer - a wings-lavel and a near-mose-level attitude - the attacker will overshoot below the defender's line of flight at a higher relative airspeed. See figure 33. The attacker is forced into this overshoot because his steep nose-down attitude combined with his rate









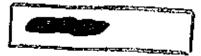


of roll and/or turn - which is dependent upon the defender's rate of roll and turn - forces him below his opponent with a higher vector velocity along the exis of the high-G roll. As a result, upon-completion of the maneuver, the defender will be above and somewhat toward the rear of his opponent. To gain a firing position, the defender need only roll off or "S" down to the attacker's six-o'clock position.

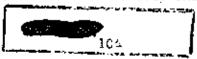
To counter the high-G roll undermeath, it is obvious that the attacker must not generate a steep nose-low attitude, then attempt to follow the maneuver. In other words, he must not interpret the roll underneath as an apparent dive for separation. To determine whether the maneuver is a roll underneath or a dive for separation, the attacker need only observe the dynamics of the defender's initial move down and out of the defensive turn. If the defender appears to fly through his longitudinal axis, he is in a dive for separation. If he appears to pivot or totate around his longitudinal axis, he is performing the high-G roll undermeath. The attacker must observe the defender very carefully to catch this difference. If he does, and notes that the defender is rotating around his longitudinal axis, he should not cut off. Instead, he can pull up, delay momentarily, then follow the defender around the roll. This will provide the attacker the opportunity to play the maneuver, hence prevent an overshoot below the defender. As a second alternative, the attacker can pull off and roll in the opposite direction. By doing this, he is not dependent upon a G and rate of roll governed by the defender's velocity, angle off and range. Instead, the attacker can pull the G necessary to play his rate of roll to reduce vector velocity and prevent an overshoot below the defender. If done properly, the reverse-roll will place the attacker at the defender's six-o'clock position. At completion of the defender's roll underneath the defender can move against either one of these counters, by observing the attacker's actions. If the attacker pulls off to initiate either counter, the defender does not complete the manauver. Instead, he relaxes G and dives for separation. If the attacker is pulling off and up in either case, this will place him in an overhead attac' with a negative delta Mach. However, the separation gained in this situation is not as great as in the other over-head attacks with a negative delta Mach. Therefore, a great deal more pressure is exerted on the defender, unless he can decaive the attacker into following his high-G barral-roll underneath. On the other hand, the high-G roll underneath has an advantage over the high-G roll over the top because the defender can observe the attacker throughout most of the maneuver, whereas in a roll over the top, he cannot. This means that if the attacker counters with a roll underneath, the defender can take immediate action, whereas in a roll over the top, he is forced to the 270° point before he can observe the attacker's counter.

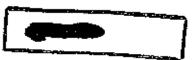
Procedures for the Bigh-C Patiel-Foll over the Top

1. Perform a defensive turn, in an effort to force your attacker to overshoot. If he does not, and is within gun firing range at six o'cle! (out 1500 feet or less) use the following procedures.



- 2. Barrel-roll over the top without relaxing any G forces. This requires extreme rudder control and very little alleron movement (see section describing adverse yaw). This maneuver will give you a rapid reduction in vector velocity and will provide a deceleration advantage because your line of flight will describe an arc above the horizon, prior to your opponent's. Your opponent will be forced to barrel-roll around the outside of your roll. Remember, you must have the necessary airspeed (300 knots or more in the F-100) before starting the maneuver.
- 3. Observe your opponent's position. When coming through the 270° point or down the opposite side of the roll, keep "coming in" with top rudder and get him committed into a nose-low attitude.
- 4. Continue rolling and keep adding top rudder to increase your nose-up attitude. This will force your opponent to slide below and in front of you.
- 5. Continue maneuvering to gain the advantage as your opponent slides below and forward. Either roll off or "S" down into his six-o'clock position.
- 6. Try to keep your opponent in sight throughout the maneuver. Be sure you have him in sight as you reach the 270° point. If he is at the top of your canopy, and to the rear, maneuver as outlined below.
- 7. Discontinue your roll-out at the 270° point and turn through the horizontal plane into the attack. Your opponent, having accomplished a reverse roll-off, will be at an angle-off, in the horizontal plane, when you are at the 270° point. To counter the reverse roll-off, you must turn into the attack at this point.
- 8. Force your opponent into an overshoot in the horizontal plane then relax G, light afterburner and dive for separation. If the attacker attempts to turn in behind you, he will be placed in an overhead attack with a negative delta Mach. Do not attempt a seissors maneuver after your opponent overshoots. You will not have enough maneuvering airspeed to successfully employ it.
- 9. If your opponent is nosc-high in a yo-yo manuser (with nose-tail separation) at the 270° point, turn 180° through the vertical plane, relax G, light afterburner and dive for separation. If the attacker attempts to follow, he will be placed in an overhead attack with a negative delta Mach.
- 10. At the 270° point, continue your roll if your opposent dots not yonyo out into an extreme nors high attitude. Since he had failed to zoom sufficiently in the vertical plane, his vector velocity, along the axis of the roll, will be greater than yours. This will force him forward and will place you to the roar and below him.





II. Maneuver (low-speed ye-ye) for a firing position.

Procedures for the Pich O Roll Undermeath

- 1. Perform a defensive turn, in an effort to force your attacker into an overshoot. If you are unable to do so, and you are within the speed requirement for the high-G roll underneath (250 knots or less in the F-100) employ the following procedures.
- 2. Roll underneath without releasing any G force. This will prevent any subsequent increase in airspead and will tend to deceive your opponent into thinking you are attempting a dive for separation.
- 3. Hold rudder in the direction of the roll all the way around the roll and play power to deceive your opponent. By holding rudder, you will successfully perform the high-G roll underneath without falling out into a steep nose-low spiral and a subsequent easy tracking solution. If your opponent was deceived into cutting off, he will be as outlined below.
- 4. Complete the roll to a wings-level, nose-level stritude. The attacker will be in a nose-low attitude below your line of flight with a higher vector velocity.
- 5. Bring your eircraft to a nose-high attitude, then roll off toward the attacker's six-o'clock position.
- 6. If the attacker is not deceived into cutting off and following you, after you initiate the roll, employ the following procedures.
- 7. Discontinue the roll, relax G, light afterburner and dive for separation, when you observe your opponent pulling up to delay, or to reverse-roll. This will place the attacker in an overhead attack with a negative delta Mach. However, separation will not be great, therefore prepare to counter any subsequent action.

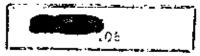
Maneuvering from a Nose-Quarter Attack

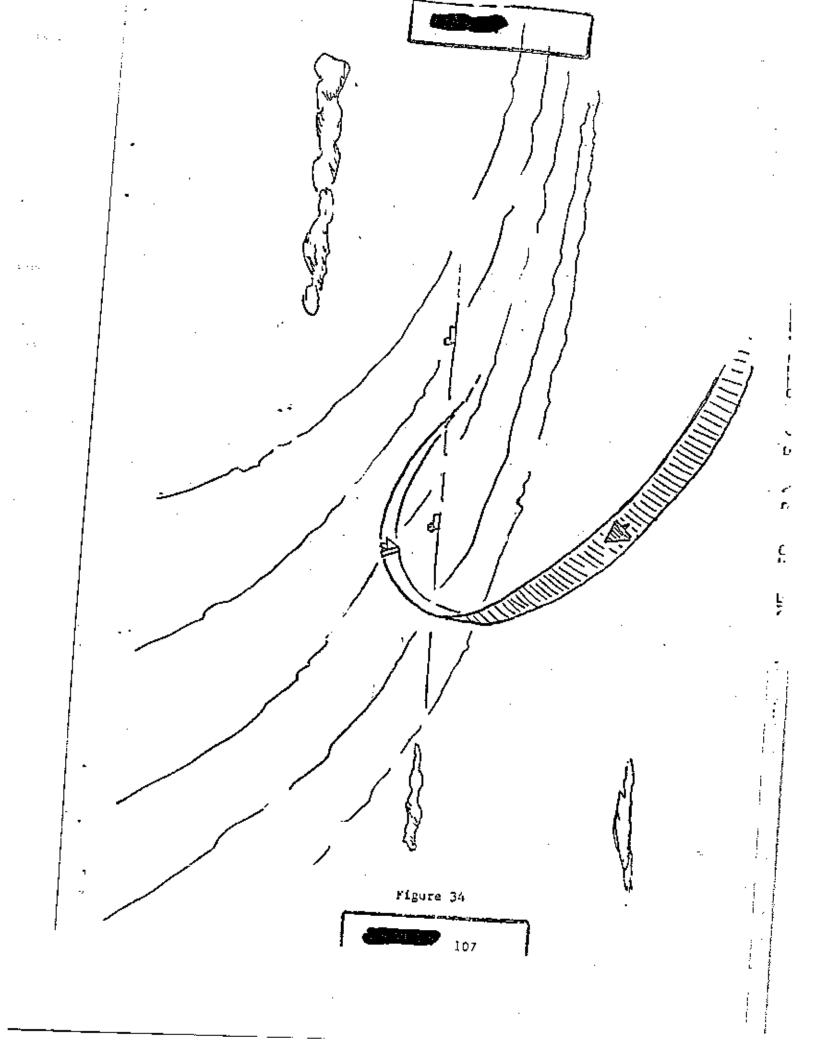
Until now, our interest has been directed to the offensive and defensive tactics involved in rear-hemisphere attacks. Now we will concern ourselves with forward-hemisphere attacks. From experience, we know many fighter-versus-fighter engagements start with the opposing fighters approaching each other's nose-quarter position. Since this is the case, it behooves us, as fighter pilots, to understand the tactics needed to gain an advantage from this position. Hence, the remainder of our discussion, in fighter meneuvors, will be concerned with the nose-quarter attack. This will complete the meneuvoring aspect of fighter-versus-fighter combat and will perpare us for

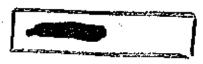


the other elements of fighter-versus-fighter operations -- Tactical Formation and Flight Tactical

To understand how we must gain an advantage from a nosce-quarter atteck, let's rafer back to our concept of turn and valority. As previously stated there are only two basic things that an attacker or a defender can do in order to gain an advantage - change direction (turn) and/or velocity. Applying these principles in a nose-quarter attack, we know that a given attacker must maneuver into the angular velocity cone in the rear hemisphere of his opponent to successfully launch a missile or deliver an effective 20mm cannon burst. This means that in a nose-quarter attack, an attacker will need a substantial rate of turn, a small turn radius and a closing velocity to gain his opponent's six-o'clock position. If the actacker fails to maneuver so that he acquires all three of these factors, he may never gain an advantage. Worse yet, he may provide his opponent an advantage. With this in mind, let's assume that an attacker notes that he is approaching an opponent from a none-quarter position. The moment the attacker visually acquires his target, he should dive and light afterburner to gain an airspeed advantage. The distance he dives will depend upon the sirpraft's acceleration and zoom capabilities (in the F-100, he can dive from 5,000 to 10,000 feet below his target). The airspeed gained from this mensuver will provide the attacker a greater forthcoming zoom than if he had maintained straight-and-level flight. The zoom will provide him freedom of maneuver in the vertical plane, so that he may effectively use the pull of gravity to increase his rate of turn and reduce his turn radius along the horizontal axis. Another advantage acquired by this dive maneuver is the element of surprise. The dive frames his opponent against blue sky and frames the attacker against the ground (assuming that the opponent does not counter with a like mineuver). From experience, we know it is generally more difficult to maintain visual contact with an adversary framed against the ground. In view of this, the opponent may fail to maintain visual contact (especially at long range before the dive maneuver is executed). The possible lack of visual contact enables the attacker to set up the next stage of his managurer - a turn for enoffset in the horizontal place. If the defender fails to maintain visual contact, the attacker will easily generate this offset. To the attacker this is the first indication of whether or not the defender actually has contact (if not the defender will fail to turn, therefore fail to provent the attacker from achieving his offset point). Assuming that the defender fauls to counter, this places the attacker below and off to one side of his opponent, on an arti-patallel course. The attacker, with an airspand adv beags, is now in position to execute a turn through the vertical and horizontal plans toward the rear homisphore of his apponent. Since the attacker is below his apponent. he may start the marrow a before the defector reaches his limitabless position. See Signre 34. The att well than execute a chardellaw type maneuver shigh-spire yoryo) toward but opposite. The chapdelie

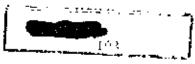




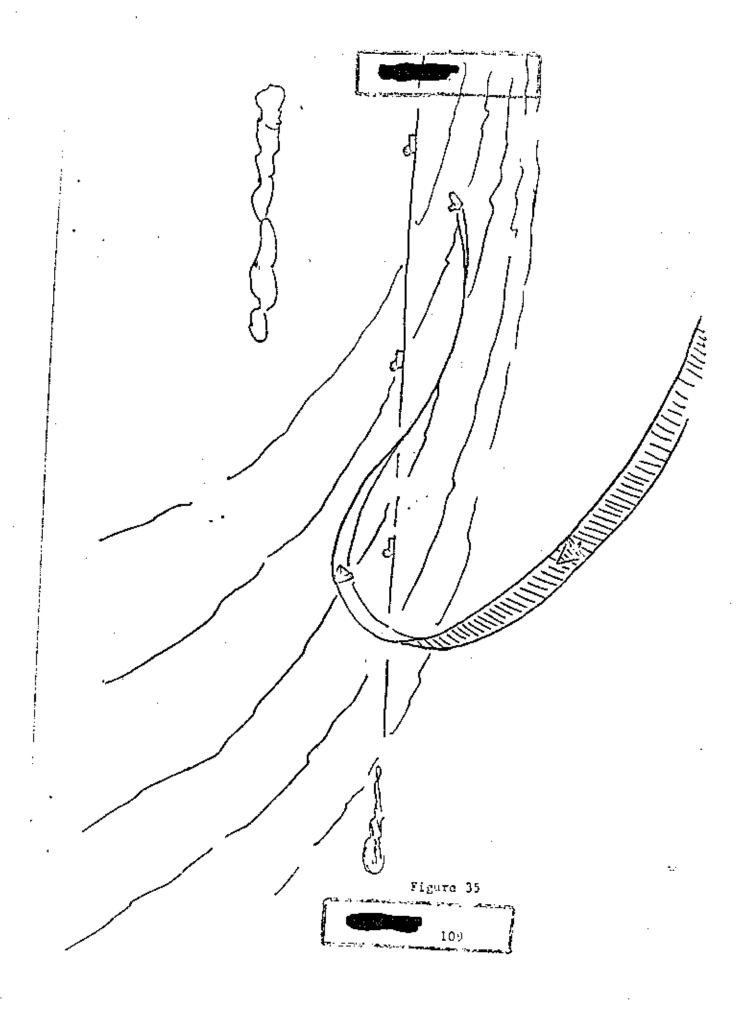


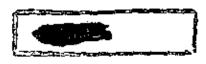
diminishes airspeed and reduces horizontal turn radius. This will prevent an overshoot, however, it will reduce his rate of turn and diminish his closing valonity, as he approaches the defendar's rear hemisphere. To prevent the defender from achieving considerable longitudinal separation, and to increase the attacker's turn rate toward the defender's six-o'clock position, the actacker should turn down through the vertical plans (low-speed yo-yo) toward the defender's six-o'clocklow position. See figure 35. The turn down through the vertical plane enables the attacker to effectively use the pull of gravity in achieving an increase in airspeed and turn rate and a decrease in turn redius. If the defender fails to counter, the attacker need only drive in underneath him, and set up for a missile attack. If the defender counters. with a turn or puli-up, after the attacker has initiated his chandelle from his offset point, the attacker still has the advantage. He need only shallow out his chandelle and zoom more through the vertical plane. This will enable him to play his opponent's counter and diminish his horizontal turn radius. However, once again, this will decrease his airspeed, hence decrease his turn rate as long as he remains in the zoom. Therefore, to gain airspeed and a more rapid change of direction (turn rate) than his opponent, he should use the pull of gravity to turn down through the vertical plane into a low-speed yo-yo below his opponent's line of flight. This will place him inside his opponent's turn at a reduced angle-off with a higher airspeed. To further reduce angle-off and longitudinal separation, the attacker need only repeat the zoom and dive below his opponent's line of flight, or zoom and perform the barrel-roll attack (a roll-away maneuver) toward his opponent's six-o'clock-low position. Even if the defender countered in like manner, after the attacker started to zoom from below and out to the side, the attacker would eventually gain the advantage, since his initial dive for airspeed and his offset give him a maneuvering advantage. The dive for airspeed provides an airspeed and rate of turn advantage. The offset below provides an initial maneuvering advantage.

To effectively counter a nose-quarter attack of this nature, the defender must decide whether he is trying to avoid a fight or to gain a kill. In either case, when the attacker starts to dive for atvapeed and a possible offset, the defender should counter in like manner. This will prayent the attacker from gaining an airspead advantage. It will also prevent him from attempting an offset, since such a managuar under these conditions would be the same as reducing the defender's angle-off. This will provide the defender some advantage. Now if the attacker approaches and stores to move past the defender, he must decide if he is trying to avoid a fight or not. If he is ettempting to avoid a fight, he should push over and dive for separation, as the attacker attempts to grow tuen int dive for a six-o'clock position. This manager by the defender will place the attacker in an overhead attack with a nagative delta Mach, with exitent longitudinal separation. The attacker will be unable to close for a missife setteck. Co the other hand, if the defender desides to stay and fight, he should we



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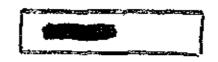


zoom and dive in the manner just discussed in an effort to gain an advantage. If the atracker is as skillful as the defander in employing this technique, this might not be a wise decision.

If the defender desires to counter an attacker who has already offset below and to the side, for his forthcoming zoom and dive, the defender should turn toward the offset and dive for separation. Since the attacker must perform a 130° change of direction, this will place him in an overhead attack with a negative delta Mach, with entrance longitudinal asparation. If the defender attempts to stay and fight, instead of diving for separation, the attacker will eventually gain the advantage because of his higher sirapeed and better position (in this situation, we assume that the attacker will employ the proper zoom and dive techniques to gain an advantage).

Procedures for the Nose-Quarter Attack

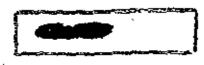
- 1. Light afterburner and dive immediately below your opponent to gain energy for your forthcoming zoom and maneuverability in the vertical plane. A dive below will also provide you the element of surprise needed for your next move.
- 2. Turn to an offset point in the horizontal plane. This will place you below and out to the side of your opponent on an antiparallel course. If your opponent fails to counter, you will have a maneuvering advantage in terms of position as well as sirspeed. In this event employ the following procedures.
- 3. Start a chandelle toward your opponent, so that you will be near the 90° point of the chandelle when you are approximately 90° angle-off from your opponent. This maneuver will reduce your turn radius and decrease your airspeed.
- 4. Turn through the vertical plane out of the chandelle, inside and below your opponent's line of flight, toward his six-o'clock-low position. A turn through the vertical plane enables you to gain your opponent's six-o'clock-low position without extreme longitudinal separation and a possible flight path overshoot in the horizontal plane, since you increase your sirspeed and turn race, and at the same time, further reduce your turn radius. To gain maximum effect, a turn through the vertical plane should be initiated as you pass the 90° point of your chandelle.
- 5. Accelerate below your opponent for an AIM-9B attack from six-o'clock-low. If your opponent counters with a defensive turn or a pull-up against your dive toward a six-o'clock-low position, employ the following procedures.
- 6. Pull up and soom from your inside-low position and repeat the soom-dive technique to gain an advantage, or barral-model (roll-away) -



out of the zoom towerd your opponent's six-o'clock-low position. Generally, the roll-away will enable you to gain your opponent's six-o'clock-low position more quickly. However, the zoom-dive technique may be more appropriate if you horizontally evershoot your opponent's flight path on the zoom, and he dives for separation after the overshoot.

Procedures for Countering the Nose-Quarter Attack

- 1. Dive the instant your opponent dives, to prevent him from gaining an airspeed and a possible offset advantage.
- 2. Do not allow your opponent to offset. If he attempts to do so, turn toward the direction of the offset. This will reduce your angle-off toward his six-o'clock position, and will give you a slight advantage if he offset; (under these circumstances, he most likely will not attempt it).
- 3. Decide whether you will avoid a fighter-versus-fighter engagement or stay and fight. If you wish to avoid the engagement, simply push over and dive for separation as your opponent moves past you on an anti-parallel course. Since your opponent must perform a 180° change of direction, this will provide you extreme longitudinal separation outside missile range. If you wish to stay and fight, employ the following procedures.
- 4. Pull up and zoom, in the vertical plane, toward your opponent as your opponent starts to move past your line-abreast position on an anti-parallel course to reduce your horizontal turn radius. While in the zoom, your airspeed and turn rate will decrease. Therefore, to acquire a rapid change of direction and to accelerate toward your opponent's six-o'clock position, employ the procedures outlined in the following paragraph.
- 5. Dive out of your zoom, below your opponent's line of flight, in an attempt to gain a six-o'clock-low position. If your opponent fails to emulate your zoom-dive technique, you will gain an advantage by reducing angle-off and moving toward his six-o'clock position. From this position, you need only repeat the process or employ the barrel-roll attack to move in for the kill. If your opponent emulates your zoom-dive technique, you will be stalemated. If this is the situation, you must use your own judgment to determine whether you should continue to fight or break off the engagement.



CHAPTER II

TACTICAL FORMATION

In air-to-air tombat, the primary purpose of tactical formation is two-fold: (I) To provide security against attacks by enemy fighters, and (2) To conduct offensive operations against enemy bombers and/or fighters. To gain security, any formation must be able to detect the attack and maneuver against it before the attackers achieve a lethal position. This means that the formation must be so constructed that attacking fighters with air-to-air missiles can be detected before they are within launch range. At the same time, this formation must possess characteristics of maneuverability and mutual support so that it can counter the attack as well as see it. These same characteristics are necessary in conducting offensive air-to-air operations.

To gain maximum lookout security against a rear-hemisphere attack, the flight must be so constructed that visual cross-cover is the maximum attainable. Two means by which a formation can increase its visual cross-cover are: (1) Increase the number of aircraft within the basic maneuvering formation, and (2) Place these sircraft line-abreast at definite intervals to increase the field of cross-cover. By increasing the number of aircraft, we provide more flight members covering the rear hemisphere. If we stack the flight line-abreast, we provide . greater cross-cover, thus increasing the probability of detecting a rear-hemisphere attack. This means that we increase look-out security. but at the same time we decrease maneuveravility. To maximize manenverability, a flight must consist of as few members as possible (a single circuaft is more maneuverable than any formation consisting of more than one aircraft) with these members stacked in-trail. From experience we know that when the number within the flight is reduced, it becomes easier for the members to keep track of and avoid one another. during any maneuvering engagement. Experience also indicates it is much easier to maneuver in-trail as opposed to line-abreast formation.

In order to acquire security, and maneuverability, we must compromise between maximum look-out security and maximum maneuverability. The extent of the compromise naeded will determine the type formation flown in a fighter-versus-fighter engagement. The increased range of AIM-93, as opposed to the 20mm cannon, forces us to construct a formation in which the compromise favors look-out security. This means that the formation will be flown very nearly line-abreast at a specified interval to pick up a missile attack at ranges of greater than 15,000 feet. To maintain maneuverability and mutual support, the size of the formation must be testricted to no more than four aircraft. If a number greater than four is employed, maneuverability and mutual support become difficult and complicated. On the other hand, if less than two sireraft are employed, the look-out capability is reduced and toutual support becomes impossible. Therafore, to provide look-out