# 3

# One-versus-One Maneuvering, Similar Aircraft

Fight to fly, fly to fight, fight to win.
Motto, U.S. Navy Fighter Weapons School (TOPCUN)

For purposes of this work, *similar aircraft* denotes fighters having essentially equal performance capabilities in all areas. Because of the human influence on the performance of manned fighters, similar aircraft are not necessarily exactly equivalent in performance, since on any given day, even with the same pilot, an aircraft is unlikely to duplicate consistently a given maneuver so that all parameters are within tolerances much closer than 5 or 10 percent. For this reason it is logical to consider performance within 10 percent to be similar in most cases. However, considering the multitude of possible design variations and the influences of each variation on the many performance parameters, obtaining similarity in all performance areas almost requires that the aircraft be of the same type. Even among fighters of the same type, fuel loads and ordnance loads and configurations can alter weight and drag enough to create performance variations well in excess of 10 percent.

In most cases combat endurance plays an important role in the significance of performance variations. The longer the combat endurance of the opposing fighters, the more telling a small performance differential can be. Available combat time for many modern fighters is on the order of five minutes or even less, so larger performance variations may be considered within the bounds of similarity.

In the present world, which contains a limited number of large arms exporters and constantly shifting political loyalties, combat between similar fighters is very likely. The fact is, performance similarity enhances the importance of soundly conceived and executed tactics for a quick and decisive victory. For this reason alone the study of ACM between similar aircraft is exceedingly valuable.

In this, and in most of the following chapters, the discussion of ACM

does not consider external environmental factors that may affect tactical decisions. In this "sterile" environment there is no concern for weather, ECM, additional unseen hostile aircraft, groundfire, or anything else that can force profound tactical changes. Except as noted, the effects of such realistic factors are covered in other chapters.

Likewise, there is obviously an infinite number of possible starting conditions for any ACM engagement. Limitations in the scope of this work require that essentially one initial setup—a roughly neutral, co-energy, forward-quarter approach scenario—be covered in detail. The tactics recommended in this chapter and in following chapters cannot be optimized for every conceivable air combat scenario, but they are selected to present a broad range of tactical concepts and principles which may be applied effectively in many commonly encountered situations. This is not to imply that other techniques might not be superior in some cases; but the methods presented here are based on sound tactical principles and should be quite effective within the limitations imposed. Caution: Even minor deviations from the stated assumptions may invalidate an entire tactical concept.

In deriving tactics for use against a similar aircraft, two basic approaches are available: the "angles" fight and the "energy" fight. These labels refer to the first objective of the engagement. In the angles fight the tactician first seeks to gain a position advantage (angles), even at the expense of relative energy, and then he attempts to maintain or improve on this advantage until he achieves his required firing parameters. The purpose of the energy fight is to gain an energy advantage over the opponent while not yielding a decisive position advantage. Once a sufficient energy advantage has been attained, it must be converted to a lethal position advantage, usually without surrendering the entire energy margin. In the case of similar aircraft, each of these tactical theories has benefits and drawbacks, depending in large measure on the weapons involved. Therefore both angles fights and energy fights are discussed.

> The guy who wins is the guy who makes the fewer gross mistakes.
>
> Lieutenant Jim "Huck" Harris, USN
> U.S. Navy Fighter Weapons School Instructor

## Guns Only

As long as a fighter has altitude and flying speed for maneuvering, and its pilot has reasonable tactical knowledge, awareness of his situation, and the will to survive, the pilot can deny a guns-tracking solution to an adversary in a similar aircraft. For this reason it is usually more practical to maneuver for the snapshot envelope; then if the opponent makes a mistake, a tracking opportunity still may be available. A reasonable snapshot envelope, as described in Chapter 1, is located in the target's rear hemisphere at close range, requires excess lead, and is enhanced by the attacker maneuvering in the same plane as the target. Attaining this envelope is the ultimate goal of the tactics described in this section.

> Everything I had ever learned about air fighting taught me that the man who is aggressive, who pushes a fight, is the pilot who is successful in combat and who has the best opportunity for surviving battle and coming home.
>
> Major Robert S. Johnson, USAAF

*The Angles Fight*

In attempting to gain a position advantage against a similar adversary, the angles tactician has essentially two choices: He can turn harder or he can turn smarter. Although the primary objective for the angles fighter is to achieve a position advantage, energy considerations cannot be ignored with impunity. An angles fighter that races around the sky with its pilot pulling on the pole as hard as he can normally will lose energy in the process. Since potential energy (altitude) is limited, this energy loss eventually will mean loss of speed. If the angles fighter becomes too slow, its maneuverability suffers, so that eventually it reaches a point where it has insufficient performance remaining to gain further position advantage, or even to maintain previous gains. The prudent angles tactician must, therefore, achieve his angular gains as efficiently as possible, so that he can defeat his opponent before his own aircraft reaches the point of critical maneuverability loss.

> In nearly all cases where machines have been downed, it was during a fight which had been very short, and the successful burst of fire had occurred within the space of a minute after the beginning of actual hostilities.
>
> Lt. Colonel W. A. "Billy" Bishop, RAF

In the last chapter two types of turns were defined: nose-to-tail and nose-to-nose. The discussion there brought out the fact that gaining advantage in nose-to-tail turns requires excess turn rate, while reduced turn radius and slower speed bring success in the nose-to-nose case. Since sustained turn radius is usually more sensitive to speed reduction than is sustained turn rate (see the Appendix discussion of sustained turn performance), nose-to-nose turns generally provide the greatest angular gain per knot of speed loss. In other words, nose-to-nose geometry is more energy efficient. For this reason, the angles tactics recommended here are based primarily on the nose-to-nose turn.

> Fly with the head and not with the muscles. That is the way to long life for a fighter pilot. The fighter pilot who is all muscle and no head will never live long enough for a pension.
>
> Colonel Willie Batz, GAP
> 237 Victories, WW-II

Besides direction of turn, another consideration of the angles fight is plane of turn. Earlier discussions showed how oblique turns reduce a fighter's horizontal turn radius, so, assuming the opponent turns level, the angles fighter can use oblique turns to increase angular gains during nose-to-nose maneuvering. Now this leaves the question, "Should the oblique turn be made nose-high or nose-low?" When two similar fighters meet nearly

head-on, the maximum separation that will result from a subsequent immediate nose-to-nose turn is about one turn diameter. As pointed out in the last chapter, at this range turn radius is the primary factor in gaining an angular advantage. Turn radius is minimized, as a rule, by pulling max-G at or below corner speed. Most fighters, however, will decelerate rapidly during such a maneuver, causing the angles fighter to lose excessive energy before a similar opponent can be dispatched with a rear-hemisphere weapon. Allowing the opponent too great an energy advantage can spell big trouble (this is discussed later in this chapter).

One answer to this dilemma is to turn nose-low, trading altitude for angles, rather than bleeding excessive airspeed. Figure 3-1 shows how this might work. At time "1" the two fighters approach head-on at roughly equal altitude and speed. Since energy nearly always seems to be a very precious and hard-to-get commodity during an engagement, both pilots should be trying to grab all they can at this point. The angles tactician has set his best energy-rate climb speed, and he is climbing with full power at that speed to gain energy (altitude) as quickly as possible. (See the discussion of climb performance in the Appendix.) Since the angles tactician would like to engage at corner speed, however, and he is currently faster, he starts a zoom climb at time "1" This zoom reduces airspeed without incurring a loss of total energy, and it also generates vertical flight-path separation, which will be useful for a lead turn.

This zoom-climb tactic is appropriate for most jet fighters at medium to low altitudes, since best climb speed normally exceeds corner speed under these conditions. Prop fighters and subsonic jets at high altitudes, how-

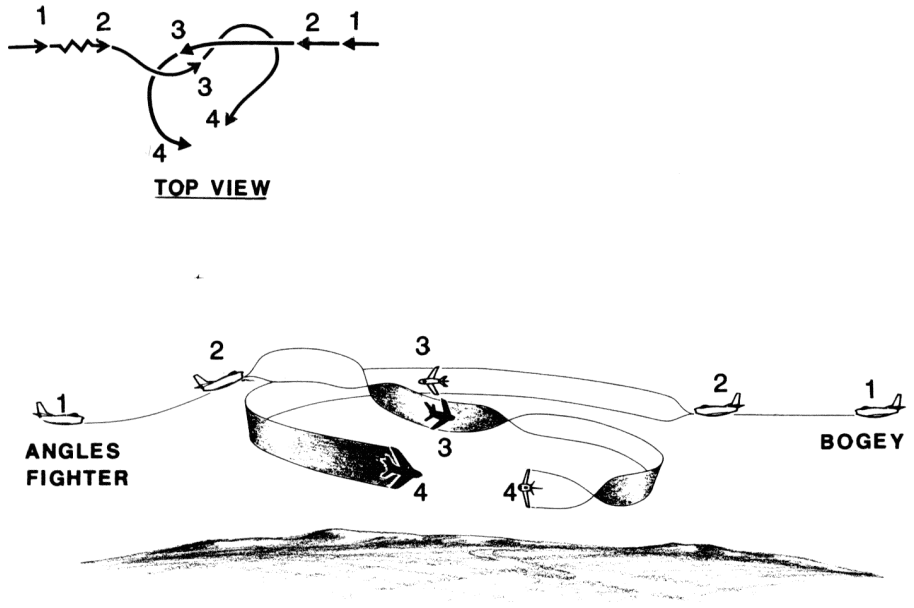


Figure 3-1. Guns-Only Angles Fight: First Phase

ever, usually climb best at speeds below the corner. If this is the case, the angles fighter should accelerate to corner speed, or as close to it as possible, and climb at that speed, even at a reduced rate. When there is no airspeed in excess of corner velocity to dissipate approaching the first pass, the zoom climb is unnecessary.

The angles tactician levels off when he reaches corner speed and turns hard right at time "2" to build additional flight-path separation laterally. As the bogey approaches, the angles fighter pilot reverses his turn and begins an aggressive, nose-low lead turn on the opponent. The objects of this initial turn are to force the bogey pilot's reaction, put him in a defensive frame of mind immediately, and generally see what he's made of. In this case the opponent is made of "the right stuff," because he counters with a hard turn of his own up toward the attack, taking away all the flight-path separation with a close pass at time "3."

> A good fighter pilot must have one outstanding trait—aggressiveness.
>
> Major John T. Godfrey, USAAF

If he is able to grab substantial angles on the first pass, the angles tactician should take advantage of the gift and continue his nose-low left turn in the nose-to-tail direction. In this case, however, the pilot reverses to set up a nose-to-nose condition. He should still be very near corner speed, and immediately after the reversal he pulls max-G in his nose-low right turn to minimize turn radius. The nose-low turn reduces deceleration at high G and also adds a little benefit from out-of-plane geometry. This max-G turn is normally performed with the lift vector pointed at, or slightly below, the bogey, causing the angles fighter to descend somewhat below the bogey's altitude while maintaining enough airspeed for vertical maneuvering. After a few seconds of this, the G is relaxed a little and the nose is started back up toward a level attitude; the maneuver is timed so that the angles fighter can be climbing up toward the bogey at the next pass.

The initial maximum-performance turn after the reversal (time "3") should place the angles fighter inside the turn radius of a bogey turning in a nearly level plane. Another reversal and a lead turn approaching the next pass (time "4") should convert the resulting flight-path separation into angular advantage. After the initial portion of the nose-to-nose turn, however, G should be relaxed to allow the angles fighter to regain some of its lost altitude and conserve airspeed. As a rule of thumb, the guns-only angles fighter should stay within about one-quarter of a turn radius or one-half of an effective guns range, whichever is less, of the bogey's altitude, and its pilot should not allow airspeed to decrease below that required to get the nose up purely vertical if necessary. These precautions add a measure of safety to angles tactics and still should enable the fighter to gain between 20° and 30° on a similar opponent on the first turn. The angles tactician cannot afford to get too greedy when he is facing a well-flown opponent in a similar aircraft.

Throughout this angles-tactics sequence, except for possibly the initial pass at time "3," the angles fighter should meet the bogey from below

coming up at each pass. This tactic encourages the opponent to turn nose-low in response, which allows the angles fighter to continue nose-low on the following turn without losing so much altitude relative to the bogey. Attacking from below also discourages the bogey pilot from making a steep pull-up prior to the pass to make use of his excess energy, since such a pull-up would, at least temporarily, increase the attacker's angular advantage. In addition, overshooting the bogey's flight path from low to high is considerably less dangerous than overshooting from above, which invites the opponent to initiate a rolling scissors. Since the bogey will probably have an energy advantage after the first pass, the angles tactician should avoid participating in a rolling scissors. If the defender pulls up sharply at an overshoot and the angles fighter pilot judges he cannot get his aircraft's nose on the bogey quickly for a gun shot, a diving extension is called for to gain separation for an escape or a return under more favorable circumstances.

Passing the bogey at time "4" with a good bite may offer the attacker a forward-quarter gun snapshot opportunity, which he should take. Being shot at places the opponent more deeply on the psychological defensive and should force a defensive reaction, which will bleed his aircraft's energy and possibly give the angles fighter greater advantage. The shooter may even get lucky and score some hits. An angular advantage at the pass also will likely cause the defender to lose sight temporarily as the angles fighter overshoots at six o'clock and flies toward the bogey's belly-side. In this situation there is a very strong tendency for the bogey pilot to reverse his turn direction to regain sight, which is exactly what the angles tactician would like. Such a reversal reinitiates a nose-to-nose condition in which the tighter turn radius and slower speed of the angles fighter should bring further gains at the next pass.

If the bogey does not reverse at time "4," the angles fighter pilot should continue to press his advantage in the nose-to-tail direction, using alternate low and high yo-yos (Figures 2-7 and 2-6) to make repeated low-to-high gun passes on the bogey, while making small angular gains on each pass. If this sequence continues, the attacker should eventually either score hits or force the defender into a reversal or zoom climb.

> Once at the enemy, you should not aspire just to strike him, but to cling after the attack.
>
> Miyamoto Musashi

In Figure 3-2 (a continuation of the engagement begun in Figure 3-1), the bogey reverses and zooms at time "4" in a climbing oblique right turn. The angles fighter also pulls up sharply inside the opponent's turn and threatens a gun shot as the defender tops out at time "5." Because the angles fighter normally has less energy, it probably will not be able to reach the defender's altitude at time "5," but all that is required for a gun shot is that the shooter draw within effective guns range with lead. Without sufficient energy to zoom out of range, the bogey is forced into a defensive pull back down toward the attacker. Figure 3-3 shows the end-game of this engagement.

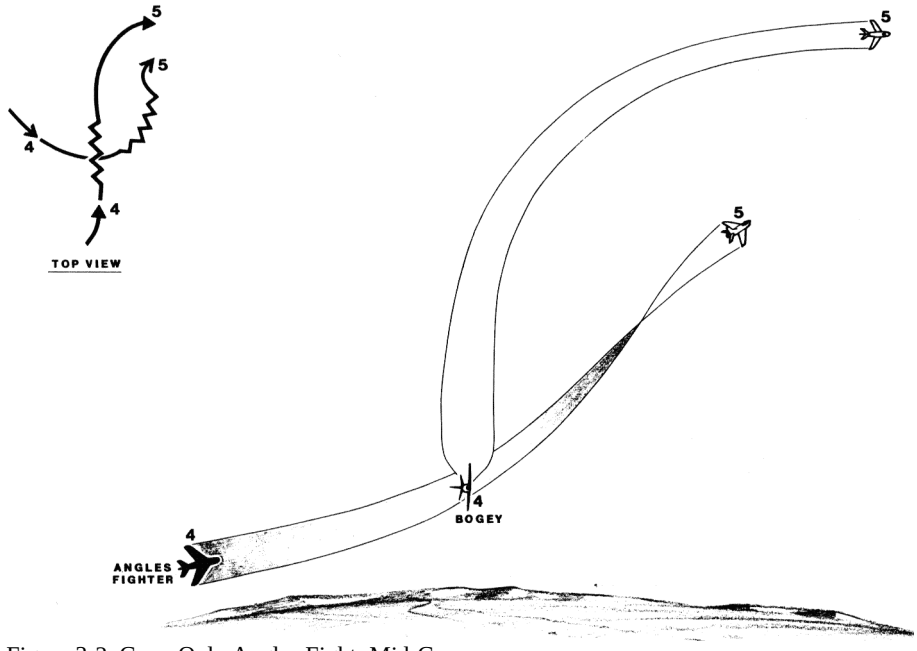


Figure 3-2. Guns-Only Angles Fight: Mid-Game

From his position of advantage below and behind the bogey, the angles tactician at this point puts everything he's got into a lead turn to position for a snapshot as the target dives by at point-blank range and too slow to defend against the shot, time "6." An in-plane, "blind" lead turn is most effective for this purpose, but, as discussed previously, this tactic takes much practice and can be risky. Normally little is lost by turning slightly out-of-plane so that the target can be kept in view over one side of the angles fighter's nose.

In the situation just described at time "6," the bogey should soon be cold meat. If the shot is missed, however, the situation could change rather rapidly. The angles fighter most likely will overshoot vertically at a lower energy level than that of the bogey. This may allow the bogey to escape or to force a rolling scissors, which would be to its advantage. Although there is probably not much that can be done at this point to prevent the bogey's escape, the angles tactician does need to be wary of the rolling scissors. At min-range he should perform a quarter roll away from the bogey and continue his pull-out. After safe separation has been gained, he can either reengage on neutral terms or escape.

There's no kill like a guns kill.

Lt. Commander Joe "Hoser" Satrapa, USN
Gunnery Instructor

*The Energy Fight*

This tactic involves building an energy advantage and then converting that energy to a snapshot position. Figure 2-15 depicts one method by which an energy advantage may be used to generate vertical separation and a possi-

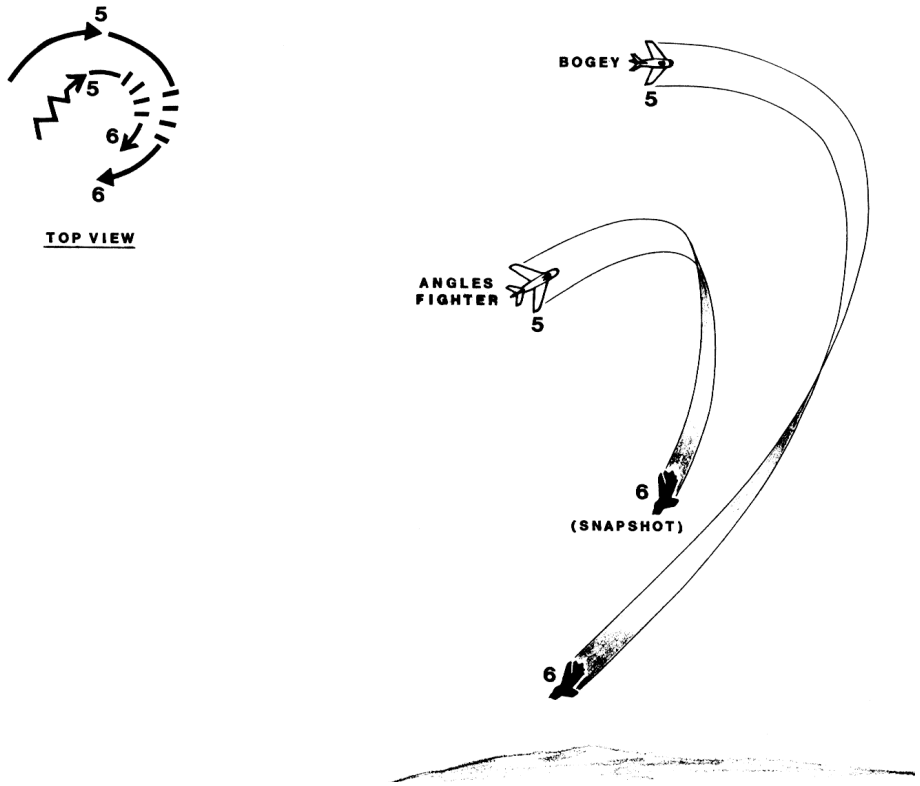


Figure 3-3. Guns-Only Angles Fight: End-Game

ble firing opportunity. Against a similar adversary, however, it may be difficult for the energy tactician to gain enough energy margin over his opponent to avoid being menaced at the top of a zoom climb.

The rolling scissors (also described in Chapter 2) provides another, probably more practical, tactic by which an energy advantage can result in multiple firing opportunities and disengagement opportunities while enabling the energy fighter to remain on the offensive throughout. Because of these advantages, the rolling scissors, as depicted in Figure 2-21, will be the end-game goal of this section. Given a reasonable initial energy advantage and good technique, the rolling scissors should result in a snapshot opportunity against a similar fighter within one or two turns. These firing opportunities are ordinarily achieved at the bottom of the vertical maneuvers, but before he initiates such a guns pass it is important that the pilot of the energy fighter attain the speed his aircraft requires for vertical maneuvering. This ensures the ability to continue the rolling scissors, retain the offensive, and generate further shot opportunities if the first shot is unsuccessful.

The outcome of the rolling scissors with similar fighters is highly dependent on relative energy states at initiation of the maneuver. Figure 3-4 illustrates a method by which the energy tactician can ensure that he has an energy advantage over his opponent before the two fighters begin the scissors. Prior to time "1" the fighters are in a forward-quarter approach situation. A fancy radar may allow some insight into the oppo-

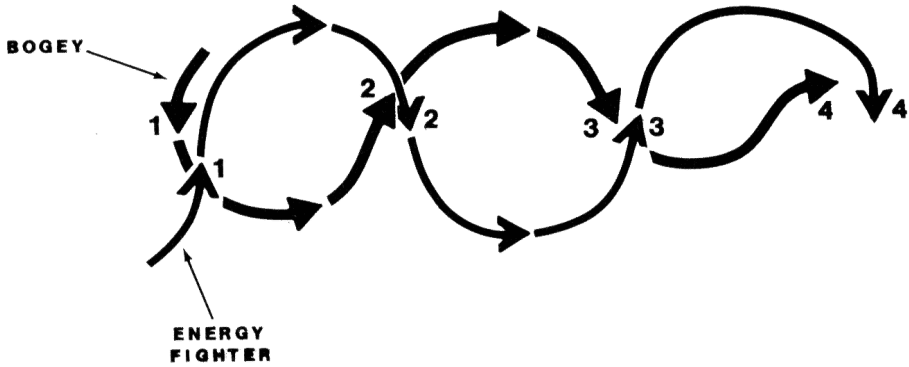


Figure 3-4. Energy Fight: First Phase

nent's speed during this period. As with the angles fight, the energy tactician should not be satisfied with a neutral start. Flight-path separation should be generated prior to the pass for a lead turn, as described in Figure 3-1. In this case, however, the energy fighter pilot is not looking for corner speed at the pass, so the break-away and lead turn will probably be made in a level plane. The energy tactician should also avoid bleeding airspeed during this maneuver to below best sustained-turn-rate speed or vertical-maneuvering speed, whichever is greater. The lead turn, therefore, may not be quite as aggressive as it is with angles tactics. If the bogey allows the energy fighter a good bite on the first pass, the lead turn should be continued in the same direction to press the advantage. The pilot of the energy fighter might consider making the transition to angles tactics in this case, since these methods are usually more effective against a nonaggressive opponent. In this example, however, it is assumed that the bogey turns into the fighter's attack, taking away all flight-path separation and generating a neutral pass at time "1"

> Aggressiveness was fundamental to success in air-to-air combat and if you ever caught a fighter pilot in a defensive mood you had him licked before you started shooting.
>
> Captain David McCampbell, USN
> Leading U.S. Navy Ace, WW-II
> 34 Victories (9 on One Mission)

After determining the bogey's turn direction at the pass, this energy fighter pilot begins a level, sustained turn in the nose-to-nose direction. If speed is greater than that required for vertical-maneuvering potential, the initial turn should be at max-G, and then G should be relaxed to maintain vertical-maneuvering speed. Since the energy tactician plans to maneuver horizontally, any vertical separation he may allow (up to about a quarter of a turn radius) at the pass is of little value to the bogey, so if the energy fighter can gain an altitude advantage at the first pass, this height should be maintained.

Once the series of nose-to-nose turns commences, the energy fighter

pilot should monitor his adversary's turn performance carefully, using his own performance as a standard. By maintaining the slowest possible speed consistent with vertical-maneuvering potential, the energy fighter will keep its turn radius tight, minimizing any angular advantage that the bogey may gain in the nose-to-nose turns. Even if the bogey is faster, it may still be able to gain a good bite on the energy fighter during the first turn by using max-G; but further significant improvement in the bogey's position during successive nose-to-nose turns will require its pilot to reduce the bogey's airspeed to below that of the energy fighter.

Once the bogey has gained a position advantage by pulling high G in the nose-to-nose turn, there is a very strong temptation for its pilot to continue this tactic to increase his advantage, resulting in rapid deceleration. The energy tactician can monitor this process by noting the bogey's angular advantage at each pass. In general, the larger the bogey's angular position gain at each pass, the greater the speed differential between the fighters will be. Large bogey gains (20° to 30°) indicate a substantial speed advantage for the energy fighter. Smaller angular gains (10° or less), however, could mean only minimal speed differential. In this case the adversary is displaying sound tactical judgment, hoping eventually to achieve a snapshot position or to force the energy fighter up with only a small energy advantage, as described in the angles-fight discussion. In such a case the pilot of the energy fighter might consider exiting the fight by use of a nose-to-tail type extension (Figure 2-18) before his opponent has gained too great a position advantage. It doesn't pay to pick on the "Red Baron."

> The smallest amount of vanity is fatal in aeroplane righting. Self-distrust rather is the quality to which many a pilot owes his protracted existence.
>
> Captain Edward V. "Eddie" Rickenbacker, USAS
> Leading U.S. Ace, WW-I
> 26 Victories

Assessment of the opponent's angular advantage is a matter of comparing relative nose positions. The easiest time to do this is when the bogey is pointed at the energy fighter. At this time the angle off the bogey's nose (AON) is zero, and its angular advantage is equal to the energy fighter's AON. So if, after the first nose-to-nose turn, the pilot of the energy fighter looks at his one o'clock or eleven o'clock position and sees the bogey's nose pointed directly at him, the opponent has about a 30° advantage. The energy tactician should continue to turn toward his opponent (although not precisely in-plane while the bogey has sufficient snapshot lead) until the bogey approaches the six o'clock region. An earlier reversal gives away flight-path separation, resulting in an increased angular gain for the bogey on the next pass without attendant speed reduction.

Assuming the bogey is improving its position rapidly with each turn, the pilot of the energy fighter should continue the nose-to-nose process until his opponent achieves between 60° and 90° of angular advantage, after which time a wings-level pull-up is initiated as the bogey crosses behind the energy fighter. If the bogey continues in a fairly level maneuver, the energy tactician then can force a rolling scissors with advantage, since his

adversary should be well below vertical-maneuvermg speed. If the bogey pulls sharply up in response, the energy fighter pilot should continue a zoom climb. In this case his greater energy should allow him to top out higher than his opponent, providing vertical separation for an attack as the bogey pilot is forced to level off or to dive (Figure 2-15).

> When your opponent lunges at you . . . feign weakness. When the opponent has come in quite close, suddenly increase the distance by backing . . . away. Come in forcibly . . . and win as the opponent shows signs of slacking.
>
> Miyamoto Musashi

A nose-to-nose turn series was described here because this maneuver makes it easier to keep sight of the opponent. Particularly as the bogey gains more angular advantage, nose-to-tail turns can result in lengthy blind periods after each pass. Another complication with nose-to-tail turns (illustrated in Figure 3-5) is that a faster-turning opponent will complete his turn, time "3" (i.e., point his nose in the general direction of the energy fighter again), at greater range. This separation allows him to accelerate without turning for some time before he is required to begin a lead turn to achieve maximum angular advantage over the energy fighter at the next pass. The period of acceleration and greater aircraft separation distances make it more difficult to judge the bogey's relative energy.

In cases where maintaining sight of the opponent is not considered to be a problem, a nose-to-tail turn series is actually superior to the nose-to-nose technique for the purposes of bleeding the bogey's energy. Once the bogey pilot has reduced his speed and turn radius slightly by making an initial hard nose-to-nose turn, he can attain further angular gains without pulling so hard on subsequent turns—and reduced bogey G results in less energy bleed. Nose-to-tail turns, however, require the bogey to continue at a greater turn rate throughout the maneuver, turning hard and bleeding energy for every degree of advantage. Even if the bogey pulls the same load

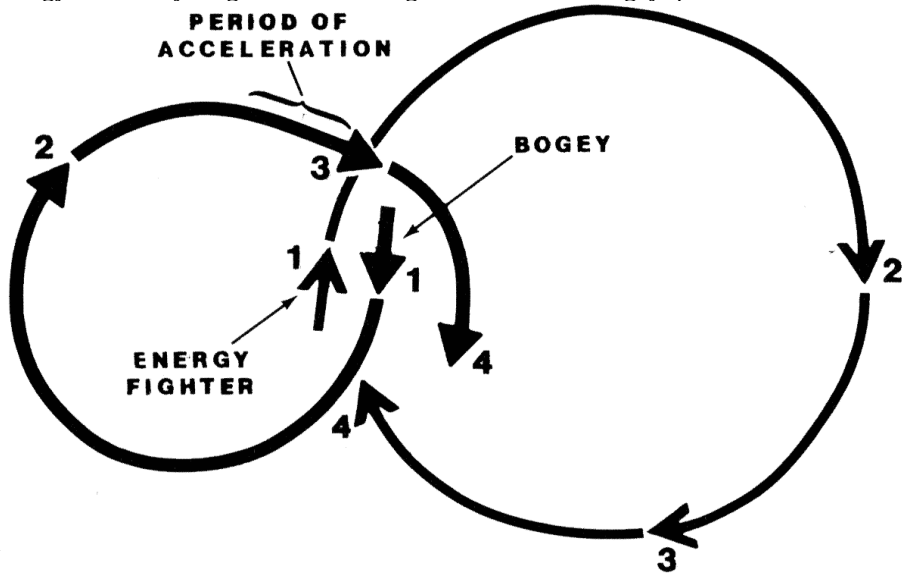


Figure 3-5. Nose-to-Tail Turn Complications

factor in each situation, nose-to-nose dynamics result in its gaining a given angular advantage in about half the time required for it to do so by nose-to-tail turns. Obviously, less time spent at high G means less energy bleed and less speed differential when the pilot of the energy fighter decides to zoom.

The greater time involved in use of the nose-to-tail method raises other points. More time spent in this predictable maneuver subjects both fighters to more danger in a hostile environment. Combat endurance is also a factor. Neither fighter may have the fuel necessary to gain a substantial advantage with nose-to-tail turns. Maintaining visual contact with the opponent, however, is the most important consideration here. If this cannot be done comfortably during a nose-to-tail turn, the energy tactician may be forced to the nose-to-nose technique, and he will just have to accept the inefficiencies involved.

Although a level turn has been specified for this portion of the energy fight, this is certainly not a requirement. In fact, there are some valuable advantages to slightly oblique diving or climbing turns, particularly in the nose-to-tail case. For instance, a diving spiral may allow the energy fighter to maintain speed while pulling its maximum structural-G limit. Since he cannot safely pull higher load factor in a similar aircraft, the bogey pilot can gain angles in a nose-to-tail turn only at a limited rate. If the energy fighter stays near corner speed, the opponent may be completely stalemated as long as altitude allows the descending spiral to continue. This technique can be very valuable, particularly when the energy fighter pilot finds himself at an initial position disadvantage. The bogey might be held outside firing parameters in this manner until its pilot loses interest or runs out of fuel and is forced to disengage. Such a stalemated nose-to-tail turn has come to be called a "Lufbery," after the American ace Raoul Lufbery, who fought with the French Lafayette Escadrille and the U.S. Air Service during World War I.

Although the nose-low method slows the rate of angular gain for the bogey in both nose-to-nose and nose-to-tail situations, a tradeoff is involved. Because of the energy fighter's higher G, the bogey is likely to pull less excess G during the maneuver, resulting in more efficient angular gains. This can mean less speed differential between the fighters when the energy fighter zooms.

The opposite is true, however, for nose-high turns. An energy fighter in a climbing turn must pull less G if it is to maintain a given airspeed. This leaves the opponent more G margin to play with, and he typically will use it to gain angles at a faster rate, bleeding relatively more energy in the process. A nose-high spiral tends to reduce the time necessary to bleed the bogey's energy by a desired amount in a nose-to-tail turn. This is seldom a requirement with nose-to-nose turns, however, and use of the nose-high technique in a nose-to-nose situation may allow the bogey to grab a lethal position advantage before the energy fighter pilot realizes it.

For the energy fight, of equal importance with reducing required engagement time is limiting the number of nose-to-tail turns necessary to bleed the bogey's energy by the desired amount. For example, if in a level or

nose-low sustained turn it takes three passes before the bogey gains about 90° of angular advantage, each pass subjects the energy fighter to a possible gun snapshot. Additionally, as the nose-to-tail fight progresses, the bogey typically overshoots at a greater angle, which results in longer blind periods and an increased chance that the pilot of the energy fighter will lose sight. By employing the nose-high-turn technique, the energy tactician may be able to reduce the number of passes required (ideally to one), thereby limiting his exposure to these hazards.

From the standpoint of energy performance, the optimum speed for an energy fighter engaged in nose-to-tail turns is about the speed for maximum sustained turn rate, assuming, of course, that this value is greater than minimum vertical-maneuvering speed. Load factor, however, should be held to only about two-thirds of the maximum sustained-G capability at this speed, and the remaining Ps should be used for climbing. Depending on the rate at which the bogey gains angles early in the first turn, this climb angle and G may need to be modified. For example, if the bogey does not turn aggressively, the energy tactician might reduce G and increase climb angle somewhat so that the bogey will make angles faster and reduce the number of passes required. On the contrary, should the opponent turn very hard, or refuse to follow the energy fighter up in its climb, it may be necessary for the pilot of the energy fighter to increase G and return to a level or even nose-low turn. The bogey cannot be allowed to gain much more than 90°, nor can it be allowed to build excessive vertical separation (such as would occur if it didn't climb while the energy fighter did), since either of these factors facilitates its ability to point at the energy fighter when the zoom occurs.

Another aspect of this energy fight which deserves attention is guns-defense technique. With each pass the energy fighter is subjected to a forward-hemisphere snapshot by the bogey. Because of the high closure involved with the forward-hemisphere approach, the adversary has very little time for careful aiming, but he still may be successful unless the energy fighter performs a good defensive jink. Assuming the attacker is approaching at about co-altitude, the defender can quickly roll wings-level, either upright or inverted, just as the bogey approaches firing range with lead. One quick, hard, out-of-plane pull, followed by a 180° roll and another pull, or a hard negative-G maneuver, is usually sufficient to spoil the shot. On the final pass of the fight, the one after which the energy tactician plans to zoom, a pull-down early in the guns defense may have other benefits. If the attacker pulls down to continue his guns pass, the energy fighter's subsequent pull-up into a zoom may result in a nose-low, vertical overshoot by the bogey, which should give the zooming fighter greater advantage in the ensuing rolling scissors.

Although energy tactics often allow the opponent to gain an angular advantage in return for an energy margin, these tactics do not have to be defensive in nature. If the energy fighter can get a good angular advantage on the opponent (on the order of 90°), lag pursuit may be used in a nose-to-tail turn to bleed the bogey's energy. The energy fighter maintains its best sustained turn rate, forcing the defender to turn harder to maintain sight

and to neutralize the attacker's position advantage. Once the bogey has regained angular neutrality, the energy fighter should have generated enough energy margin to begin vertical maneuvering, as depicted in Figures 2-15 and 2-19. This technique is much safer than allowing the opponent an angular advantage.

> In contests of [tactics] it is bad to be led about by the enemy. You must always be able to lead the enemy about.
>
> Miyamoto Musashi

So far the assumption has been made that the opponent will maneuver near horizontally; but what if he instead pulls up steeply after the first pass? By maneuvering out-of-plane, the bogey may be able to make a high-side attack on the level-turning energy fighter, forcing a defensive pull-up and immediate entry into a rolling scissors. If the bogey has an energy advantage at the pass (a factor that may be difficult to determine), a rolling scissors could be to its benefit early in the engagement. When the bogey makes an oblique nose-high turn at the first pass, the energy fighter can counter with a nose-to-tail turn, which should prevent the angles fighter from making gains without incurring an energy penalty. For near-vertical bogey maneuvers, the energy tactician should turn only enough to gain sight of the bogey; then he should continue a climb at optimum-climb airspeed to gain separation. As the bogey approaches the top of its zoom, the energy fighter can begin an oblique turn back toward the bogey in the nose-to-tail direction. During his come-back turn the pilot of the energy fighter should keep his lift vector on or slightly below the bogey to reduce vertical separation to within a quarter of a turn radius by the next pass, and he should pull hard enough to limit the bogey's angular gains to 90° or less. If possible, the energy tactician should not allow his speed to bleed below that required for vertical maneuvering.

> If you are thoroughly conversant with [tactics], you will recognize the enemy's intentions and thus have many opportunities to win.
>
> Miyamoto Musashi

*Comparison of Angles and Energy Tactics*

In the guns-only scenario, the angles and the energy techniques discussed may both be effective. Angles tactics are inherently more aggressive, placing the opponent in a defensive position early in the engagement, and they can have considerable psychological impact, particularly on an inexperienced adversary. This technique is also generally quicker than energy tactics, an important consideration when a fighter is limited by very short combat endurance.

Energy tactics, on the other hand, require more patience and training. Speed control is very important, as is the ability to judge the bogey's energy state accurately. This technique also demands proficiency in the rolling scissors, which is a difficult maneuver to master. On the positive side, except for the possibility of a forward-hemisphere snapshot, which normally can be defeated by a small jink on each pass, the energy technique

discussed here is inherently safer than angles tactics. As long as the bogey's angular advantage is limited to approximately 90°, and a vertical move is not initiated with insufficient energy advantage, separation and termination of the engagement are possible throughout the fight.

By comparison, the angles technique does not afford sufficient opportunity to assess the opponent's energy. Once the vertical move is begun, the pilot of the angles fighter is "betting the farm" on his ability to force the bogey back down first. If he is unable to accomplish this because of insufficient energy or because of adept maneuvering by the adversary, the angles tactician may find himself at the top of his zoom, out of airspeed and ideas with nowhere to go but down, and with an angry enemy above. Some insurance against this condition is provided by the angles fighter maintaining at least enough airspeed for a vertical zoom climb.

With any of the tactics outlined here, whenever the opponent makes a forward-quarter approach, consideration should be given to attempting a short gun burst at the pass. Although this is generally not a high-percentage shot, it is useful in establishing offensive and defensive psychological sets between the opponents, and it may disrupt the adversary's game plan. The pilot should assess the possible value of this shot against its effect on his own maneuvering requirements and ammunition supply.

> Every time your opponent attempts to dive at you or attack you in any way, the best thing to do is to turn on him, pull the nose of your machine up, and fire.
>
> Lt. Colonel W. A. "Billy" Bishop, RAF

Unless a pilot has extensive training in energy methods, the cautious use of angles tactics is probably preferable in this scenario. With similar aircraft, however, it is often necessary to take what the opponent will allow. For instance, if the enemy appears tentative in the first turn, the experienced fighter pilot will generally "go for the throat" with aggressive but controlled angles tactics. On the other hand, faced with an aggressive opponent, the best course might be to "finesse" him with energy tactics.

In the one-versus-one-similar scenario, it quite often becomes advantageous to switch tactics during the engagement. For example, if the fight is begun using aggressive angles tactics and the opponent matches angle-for-angle through one or two turns, odds are very good that the engagement will quickly degenerate into a dangerous slow-speed flat scissors at low altitude. The outcome of such an engagement often rests on which pilot first loses control and crashes or runs out of fuel. Normally the angles tactician should not allow the engagement to reach such a stalemate; he should make the transition to an energy fight instead. This is usually accomplished by converting to a nose-to-tail turn at the next pass and relaxing the G to the minimum value required to keep sight of the bogey. This turn is continued, allowing the aircraft to accelerate toward best sustained-turn-rate speed (or climbing in the low-G turn if the aircraft is above this speed), adjusting G and climb/dive angle so that the enemy gains about 90° by the next pass. At this point excess airspeed is traded for an altitude advantage by the methods detailed previously. If a fighter is

very slow when the pilot commences using energy tactics, it may be necessary to dive the aircraft in the turn to pick up minimum vertical-maneuvering speed before starting the zoom. Care must be taken not to delay the transition to energy tactics so long (i.e., until the fight is too low and slow) that insufficient height is available for such a maneuver.

> When reaching a stalemate, win with a technique the enemy does not expect.
>
> Miyamoto Musashi

The converse case, when the opponent refuses to take the angular advantage offered by the energy fighter, may also arise. This situation should become apparent before completion of the first nose-to-tail turn, and it invites the energy tactician to begin angles tactics, normally by starting a low yo-yo from across the circle.

Recognizing the need for, and making, tactical transitions such as these are signs of great experience in a fighter pilot. Usually, once implementing a tactical plan a less-experienced pilot will continue it to its conclusion.

### Rear-Quarter Missiles Only

Rear-quarter (RQ) AAMs, as discussed in the weapons chapter, are most often heat seekers. As with other missiles, they can be expected to have minimum- and maximum-range limits and aiming requirements in addition to their AOT boundaries. Although this firing envelope (min-range, max-range, and AOT) varies greatly with fighter and target speeds, altitudes, maneuvers, and other factors, for simplicity in this section it will be assumed to be fixed and to have constant min- and max-range limits and AOT boundaries of plus or minus 45°. Even though this envelope is usually much larger than that required for a gun snapshot, it is not necessarily easier to satisfy. This is partly because of the relationship between an attacking fighter's nose position (aiming) and its resulting maneuver (position). In order to reach a certain position in space (e.g., the firing envelope) conventional fighters must attain strictly defined nose positions; but the nose position required for the fighter to reach the firing envelope may not satisfy the missile's aiming requirements. The aiming requirements for this section of the discussion are boresight, i.e., the fighter's nose must be pointed directly at the target (AON equals zero).

With guns, maximum range is one of the most severe limitations, but it can often be satisfied by use of lead-pursuit techniques. Fortunately for this weapons system, lead pursuit is compatible with the lead-aiming requirement. In addition, the other envelope constraints, min-range and AOT, are sufficiently nonrestrictive for the snapshot so that they too may be satisfied simultaneously.

For RQ missiles, min-range and AOT are usually the toughest envelope constraints to meet. Unfortunately, pure pursuit, which is compatible with the assumed aiming requirements, results in decreasing range and increasing AOT against a maneuvering target. This is exactly opposite to the desired effect. Lag pursuit, which tends to increase range and decrease AOT, is much more compatible with RQ missile requirements; however, once a firing position is attained, this technique usually leaves the fighter

with a large AON that must be reduced to zero in order to satisfy aiming constraints. Before this can be achieved, a target with comparable turn rate will probably have increased AOT beyond firing limits once more. This situation highlights the value of missile off-boresight capability.

A further difficulty arises from the min-range boundary in conjunction with an AOT limit and a maneuvering target. Figure 3-6 illustrates the "envelope rotation effect." This figure depicts a maneuvering target at times "1" and "2" along with the missile-firing envelopes appropriate to its positions at those times. Although depicted here in two dimensions, the envelopes are actually three-dimensional cone segments rather than flat planes. The centers (hearts) of these envelopes are also shown, as well as the track required if the attacker is to maintain position at the center of the firing envelope. Normally an attacker is not required to maintain such a rigid position, but this example serves to illustrate the movement of the RQ missile-firing envelope and the effects of target turn rate and range on that movement. In addition to the velocity of the target itself, the envelope rotates at a speed proportional to target turn rate times range. The faster the target's speed and turn rate, and the greater the missile's min-range limit, the more difficult it is for the attacker to maneuver into, and remain inside of, the firing envelope for any length of time.

Because of the combined effects of the flight path—nose position inter-relationship and the envelope rotation effect, tactics designed for the use of RQ missiles against similar aircraft usually focus on reducing target turn-rate capability to a minimum while retaining a performance advantage for the attacker. Energy tactics are uniquely suited to this purpose. Since

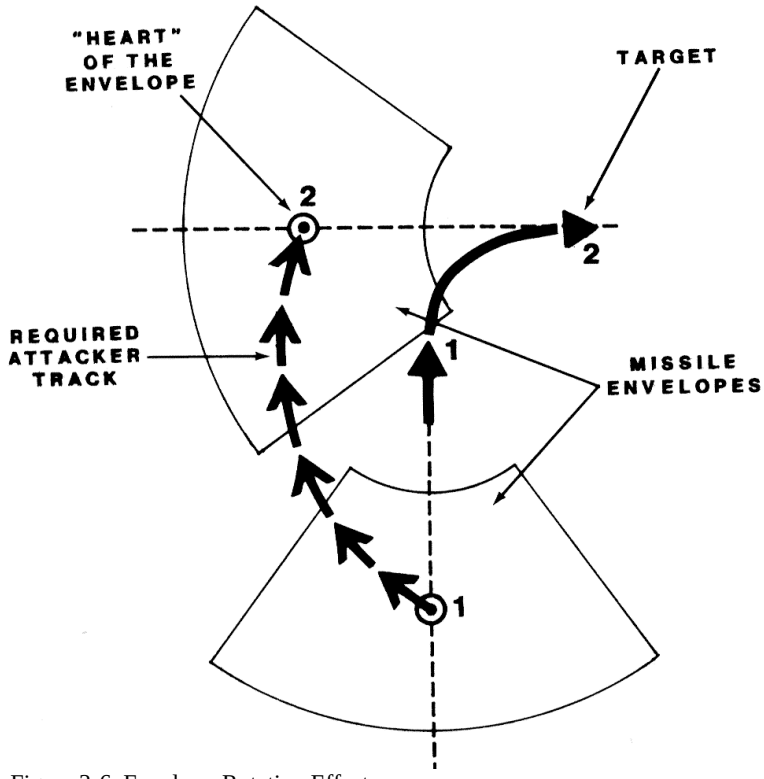


Figure 3-6. Envelope-Rotation Effect

conventional aircraft generate turn-performance capability by maintaining speed within certain limits and by sacrificing altitude to gain a gravity assist, total energy (speed and altitude) must be considered in achieving a turn-performance advantage. Unless one fighter is able to generate a significant energy advantage, the usual loss of energy during the engagement often results in something resembling a slow-speed flat scissors or a stalemated nose-to-tail turn at tree-top level.

> I never went into the air thinking I would lose.
>
> Commander Randy "Duke" Cunningham, USN

*The Angles Fight*

The angles tactics outlined for the guns-only scenario are not as well suited for the RQ missiles case, but they may be successful with minor modifications. Referring to Figure 3-1, the angles fighter no longer has the threat of a gun snapshot at time "4" to force the bogey up, out-of-plane, in a nose-high move. This gives the bogey pilot freedom to continue a level or nose-low turn, leaving the angles fighter temporarily in an offensive, rear-hemisphere position; but with an energy deficit, and probably a turn-performance disadvantage, the pilot of the angles fighter may have a difficult time improving on or maintaining his position. In such a case, the angles tactician might perform a low yo-yo after the overshoot to continue pressure on the bogey.

Faced with an overshooting situation at time "4," it is likely that the bogey will attempt to capitalize by reversing nose-high, as shown in Figure 3-7. If so, the angles fighter pilot should pull sharply up to point at the

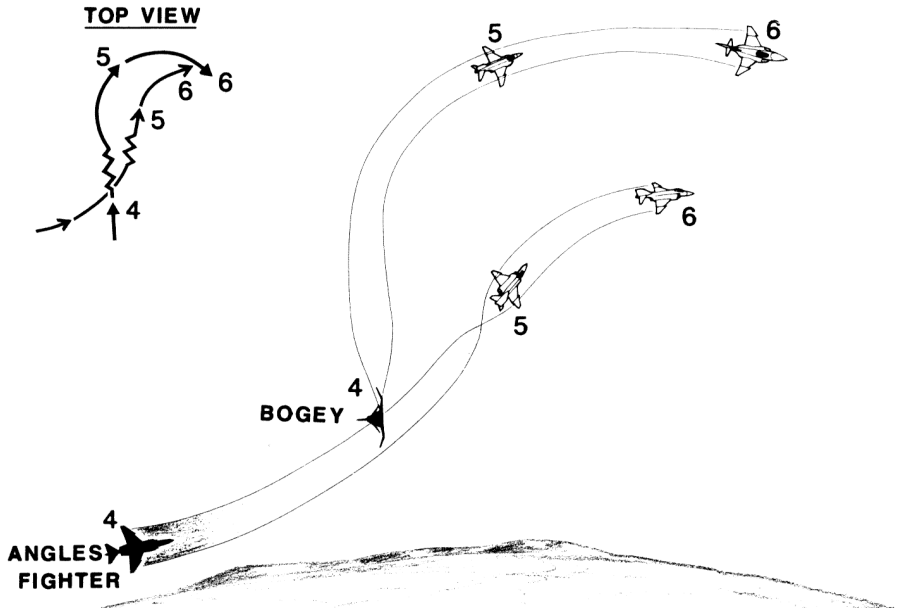


Figure 3-7. Angles Fight (RQ Missiles): Mid-Game

bogey and threaten it as quickly as possible. If he is unable to point at the target and force it back down, the attacker should pull for a position behind and below the bogey, as shown at time "5." The angles fighter should climb as close to the bogey's altitude as possible at time "5," while retaining enough speed for maneuvering. The desired position at time "6" is slightly behind and beneath the bogey, with minimum nose-tail separation and the angles fighter's fuselage aligned as closely as possible with the bogey's.

At time "6" both fighters will be near minimum-controllable airspeed. The angles fighter's position forces the pilot of the high fighter into a steeply banked turn, or a series of turn reversals similar to a flat scissors, in order to maintain sight of his opponent behind and below. The angles tactician should maneuver as necessary to remain out of sight on the bogey's belly-side. Concern over his opponent's position should eventually cause the bogey pilot to pull his aircraft's nose sharply down in order to increase his turn performance. Figure 3-8 depicts the end-game.

After the bogey pilot has committed his nose steeply down, the angles fighter should continue a level turn until the bogey approaches co-altitude. At that point the pilot of the angles fighter can roll inverted and pull his nose sharply down toward vertical (time "7"). After overshooting the altitude of the angles fighter, the bogey pilot will usually begin a pull-out to increase AOT and maintain sight. If his turns are properly timed, the angles fighter pilot may be able to pull his nose to the target and fire (time

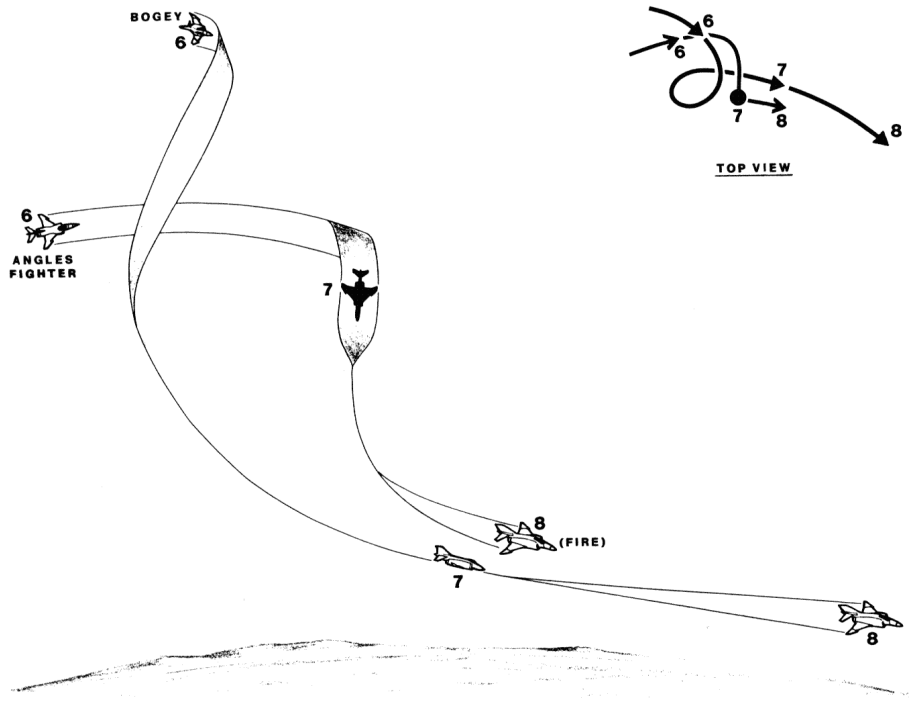


Figure 3-8. Angles Fight (RQ Missiles): End-Game

"8") before AOT increases beyond limits. Should the attacker begin his pull-down too early, he will have insufficient nose-tail separation and probably will induce a defensive spiral. If the pull-down is performed too late, the target may generate enough AOT in its pull-out to preclude a valid shot.

Timing is very critical to this end-game, and the shot opportunity will be missed quite often. When timing the pull-down at point "7," it is usually preferable to err on the late side, rather than be early. Too much nose-tail separation resulting from a late vertical pull normally allows the angles fighter to maintain an offensive position; but too little separation often results in a defensive spiral, from which either fighter may gain advantage.

If it is obvious at about time "7" that a shot will not be forthcoming, the attacker has the option of disengaging or continuing the fight. Disengagement may be accomplished by rolling opposite to the direction shown in Figure 3-8 and extending away from the bogey. When a pilot is separating from a missile fighter, however, it is imperative that it be kept in sight until maximum firing range has been exceeded. Accelerating to maximum speed and diving to low altitude usually aid disengagement by reducing the maximum firing range of a hostile missile.

If the angles tactician chooses to pursue the bogey after a missed shot, he can expect his opponent either to extend for separation or to come back in a nose-high maneuver, which often results in a rolling scissors. Therefore the attacker should be careful to attain his vertical-maneuvering airspeed before pulling out of his dive, even if this requires overshooting the bogey vertically. The threat of the angles fighter deep in his rear hemisphere may induce the bogey pilot to pull out at too slow an airspeed, giving the angles fighter an advantage in the ensuing rolling scissors.

*The Energy Fight*

The energy tactics described in the guns-only section are almost entirely relevant to the RQ missile scenario. Although this scenario eliminates the threat of a forward-hemisphere gun shot with each pass, there are other dangers inherent in the use of energy tactics with these weapons. For instance, although these missiles are termed "rear quarter," a very slow target with little G capability is unable to present a high LOS rate to the missile in its terminal phase and therefore may be vulnerable at much greater AOT than a highly maneuverable target would be. The energy fighter will be slow and vulnerable at the top of its vertical maneuvers. Going vertical without sufficient energy advantage, allowing the bogey to gain more than 90° of position advantage, or pulling-up substantially before the bogey crosses six o'clock may allow the opponent to get his nose on the energy fighter for a beautiful look-up shot. Although these errors can also cause trouble in the guns-only scenario, they are even more deadly here since increased range of the missile can offset a considerable target height advantage over the shooter.

It can be expected that more turns in the rolling scissors will be required to satisfy RQ missile parameters than to reach the gun snapshot envelope.

As the energy fighter gains advantage in the rolling scissors, it will soon be able to point at its opponent for a short period of time during the bogey's pull-out. The sooner a missile can be pointed at the target, the earlier the bogey pilot will be required to begin his pull-out in order to increase AOT beyond the missile's limits. This threat may induce the defender to start his pull-out before he achieves his desired speed, and it often leads to increased advantage for the energy fighter on the next loop of the scissors. The energy tactician can hasten this process by performing an earlier, more aggressive lead turn over the top of his loop. Each cycle of the scissors will generally result in less AOT as the energy fighter points down at the bogey.

Figure 3-9 shows the end-game of this scenario. At time "1" the energy fighter is in a very advantageous offensive lag-pursuit position at the bottom of its rolling-scissors maneuver. As the bogey continues its oblique loop, the energy fighter pulls up vertically. Approaching the vertical attitude, the pilot of the energy fighter projects the bogey's future flight path and rolls to place the lift vector ahead of the bogey's position (time "2"). He then pulls down smartly toward a nose-down vertical attitude once more, but not before the bogey pilot has committed his nose down. Ideally, as the energy tactician begins to pull down over the top of his loop, he would like to be directly above his opponent. The nose should then be pointed at the target as quickly as possible, and the shot taken (time "3") before the bogey can generate too many angles.

In the guns-only energy fight, a vertical pull-up was prescribed for entry into the rolling scissors. The vertical pull-up is the most energy-efficient method for converting excess airspeed to altitude; but this luxury may not be always available to the pilot of the energy fighter, especially against a missile-equipped opponent. The increased range and relaxed aiming requirements of these weapons may allow the angles fighter to pop its nose up, point, and fire even before the energy fighter can complete its zoom. One technique for preventing this involves substituting a spiral pull-up, illustrated in Figure 3-10, for the wings-level one. After the bogey's energy has been bled, and the decision to trade airspeed for altitude advantage has been made (time "1"), the energy tactician should begin to pull his fighter's nose higher and higher, in a positive manner, while still continuing to turn in the nose-to-tail direction. This forces the angles fighter (bogey) to turn considerably farther to point at its target. The energy fighter pilot must watch the bogey carefully over the inside shoulder, and monitor its nose position closely. Initially the bogey pilot can be expected to attempt to follow the energy fighter up into the spiral, continuously pulling his nose directly upward and around toward his target, and he may appear to be gaining angles. Eventually, though, as the spiral steepens, the bogey's angular gains will slow, and then its climb angle will appear to stabilize (time "2"). This is an indication that the bogey no longer has the airspeed necessary to get its nose up to point at its target, and it is the energy tactician's clue that it is now safe for him to steepen his climb to near vertical, seeking a position above and behind the bogey. This is done by leveling the wings and pulling toward pure vertical. The bogey then can be reacquired over the opposite shoulder, and the roll and flight-path angle

can be readjusted to bring the energy tighter to a position above and behind the opponent (time "3"). Such a position makes it extremely difficult for the bogey pilot to maintain sight. Should the bogey hold its nose up and continue to turn during this time, the energy fighter can continue its zoom to achieve maximum height advantage, remaining unloaded as much as

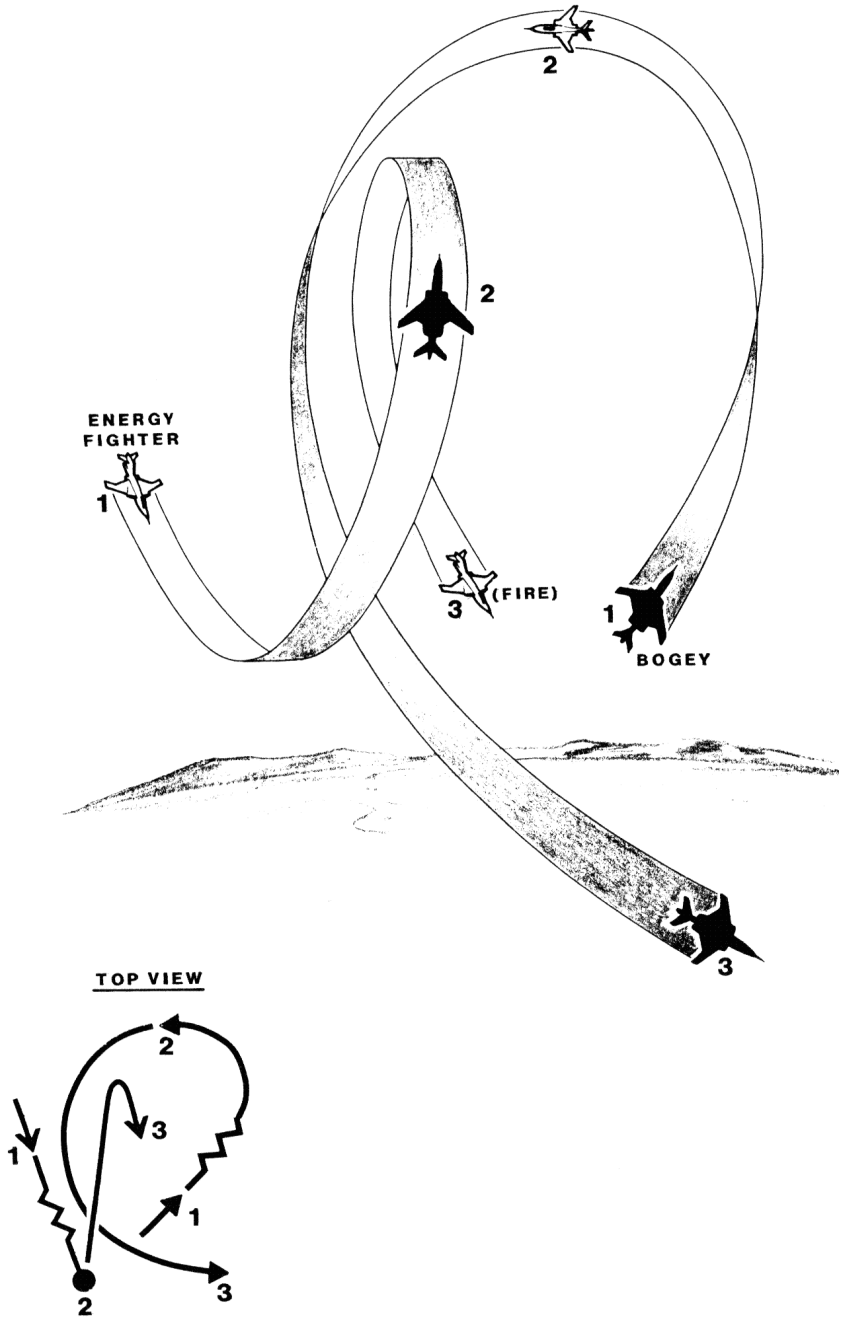


Figure 3-9. Energy Fight: End-Game

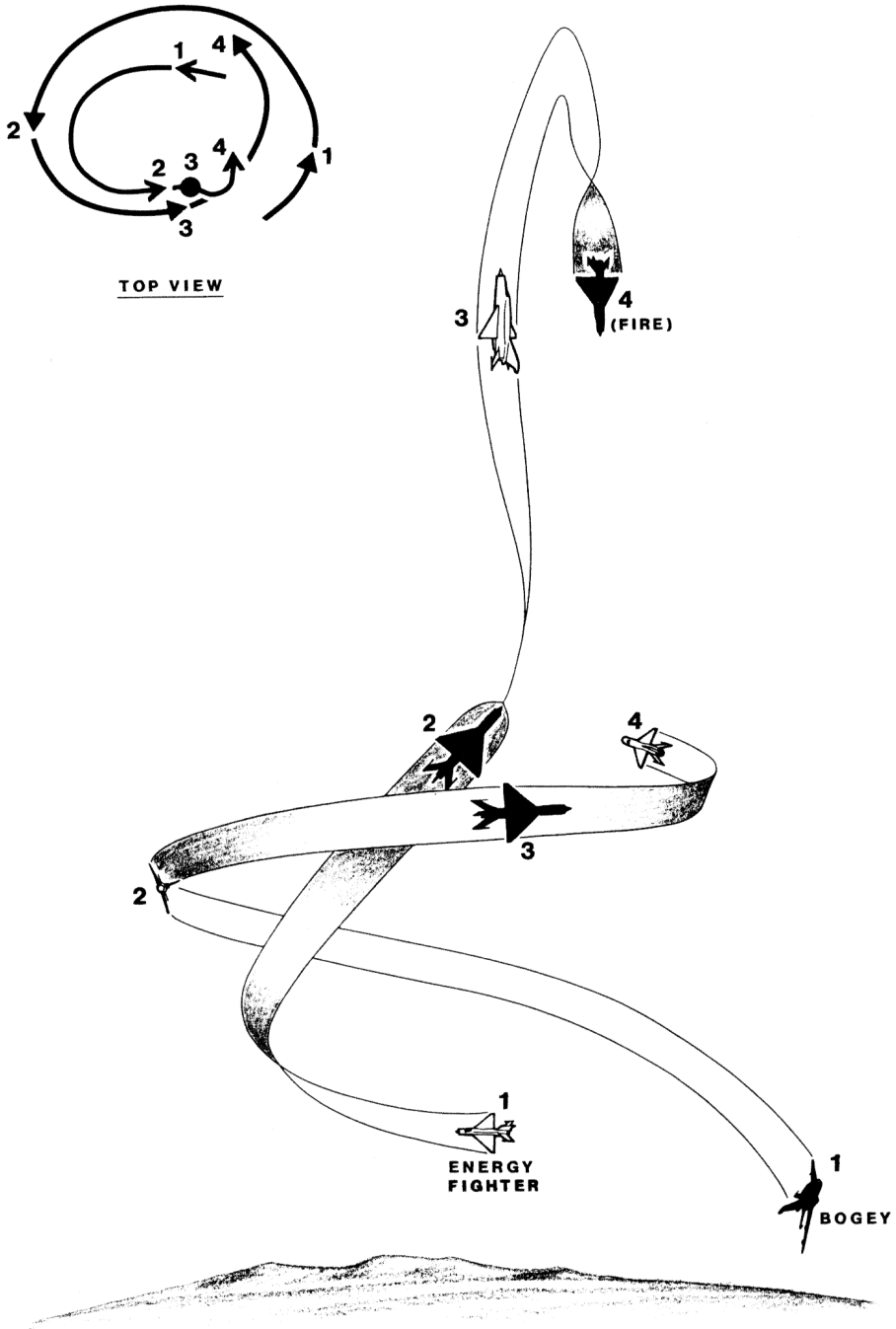


Figure 3-10. Modified-Zoom Maneuver

possible. Approaching the peak of his zoom, the pilot of the energy tighter drops his nose, points at the target, and fires (time "4"). Even if the shot available at this point is a high-angle one, the bogey should be very slow, unable to break upward toward the missile, and too slow to present the

missile with a tracking-rate problem, even at 90° off the tail. As long as the missile can acquire the target, probability of a hit is usually high. In any case, the bogey's defensive maneuver undoubtedly will put it in a vulnerable position for a follow-on shot.

The timing of the energy fighter's vertical reversal depends on many factors, including missile min- and max-range, probability of missile target acquisition as angle-off increases, and aircraft turn radius. The last of these factors involves the possibility of a dangerous vertical overshoot in case the target is not destroyed, so at least one minimum-turn-radius separation is desirable before committing the nose down. Should such an overshoot occur, it will be necessary for the energy tactician to perform a nose-to-tail extension to disengage or to recommence energy tactics. If at any time during the zoom the bogey's nose falls, it is often necessary to terminate the zoom, point, and fire quickly before the target exceeds max-range. Vertical-reversal technique is quite dependent on aircraft handling qualities (vertical-reversal technique is covered in greater detail in the next chapter).

This actual combat example of the spiral-zoom technique is found in *Thunderbolt!* by Major Robert S. Johnson.

> Habit brought my head swiveling around to look behind *me.* I was just in time to see a *Focke-Wulf* bouncing, nose twinkling from the .30-calibers. My left hand slammed forward on the throttle, my right hand hauled back and left on the stick, my heart went to the top of my head and the *Thunderbolt* leaped upward. I racked the [ug into a tight left climbing turn, staying just above and in front of the pursuing *Focke-Wulf.* ... To get any strikes on me the [German] first had to turn inside me, and then haul his nose up steeply to place his bullets ahead of me. The *Focke-Wulf*just didn't have it. At 8,000 feet he stalled out while the *Thunderbolt* roared smoothly; I kicked over into a roll and locked onto his tail.[1]

*Comparison of Angles and Energy Tactics*

Again, most of the comments made in the guns-only section apply to this case, except that energy techniques are more dangerous in this environment. Although they are more difficult in this scenario, angles tactics are still effective, and they offer the added advantage of an offensive position throughout the engagement.

> It should not be taken that one must always be the first one to attack regardless of the situation or circumstances, but at the same time, it is generally desirable to be the one to initiate the attack and thereby put the opponent in the defensive position.
>
> Miyamoto Musashi

**All-Aspect Missiles Only**

As discussed in the chapter on weapons, all-aspect missiles generally employ radar or IR guidance and can be fired at a target from any direction. The performance of both of these guidance systems usually is enhanced when the weapon is looking up at the target with a clear-sky background. Although technically all-aspect capable, most of these weapons are better in some situations than in others, with beam aspects often causing the

most difficulty. As with other missiles, these also have maximum- and minimum-range limits and aiming requirements. Although many all-aspect missiles are also off-boresight capable, guidance is usually optimized when the missile is fired within a few degrees of the target LOS (often with a small amount of lead); so for the purposes of this section all-aspect missiles will be assumed to be limited to a boresight launch.

Inherent in all-aspect capability is the opportunity for a forward-quarter shot before the first pass of the engagement, possibly even beyond visual range. Assuming such an opportunity is available, this shot should not be passed up, particularly since a similarly equipped opponent may not hesitate. A missile in the air prior to the pass establishes a psychological set between the combatants, placing the pilot of the target fighter immediately in a defensive frame of mind. Moreover, such a shot must be honored by a defensive maneuver that almost surely disrupts the defender's game plan, and it usually places the firing aircraft in an offensive position and at higher energy than its opponent even before the maneuvering begins. Since maneuvering is the prime concern of this section, however, it will be assumed that neither aircraft has a firing opportunity prior to the first pass.

In a visual engagement with all-aspect missiles, minimum-range and aiming constraints are usually the most difficult to meet. Again, these restrictions oppose each other, since the usual boresight or lead-angle aiming requirement tends to reduce separation.

*The Angles Fight*

The tactics described for the rear-quarter AAM, simply a less capable version of the weapon in this scenario, are largely applicable and will result in rear-hemisphere firing positions, as before. Improved aspect capability, however, makes the firing envelope much easier to reach and results in fewer missed shot opportunities.

Referring to Figure 3-1, the first phase of the angles fight recommended for both guns and RQ missiles, an all-aspect missile shot may be available between times "3" and "4." Aircraft separation at this point can be expected to be about one fighter turn radius, which might satisfy the min-range requirements of some missiles when they are employed by certain fighters.

The mid-game of this angles fight, as shown in Figure 3-7, may also offer a firing opportunity at time "5." Although the aircraft separation at this point is likely to be less than nominal missile min-range, the typical slow speed and lack of maneuverability of the high fighter in this situation can make it vulnerable.

The end-game of this engagement, Figure 3-8, remains the same as for the RQ missile case, except that greater AOT is allowed for the shot. It should be noted here that the final firing position produced by these tactics is a look-down shot, probably with negative closure (i.e., increasing range). Such parameters can cause problems for many all-aspect missiles, particularly those with radar guidance.

Although these tactics may be effective, they do not take full advantage of all-aspect missile capabilities. Figure 3-11 illustrates a somewhat clean-

er approach. Here the nusc-to-tail turn is used to generate the aircraft separation necessary to satisfy missile min-range constraints. At time "1" the fighters meet in the standard forward-quarter approach. Minimum lateral separation and an angular advantage at the pass are optimum for this method. As the aircraft pass each other, the angles fighter begins a nose-to-tail turn across the bogey's six o'clock. Between times "1" and "2," the opponent's aspect should be monitored closely, and the angles fighter should turn just hard enough for it to match the bogey's turn rate. On reaching time "1" a neutral position with about 90° of target aspect, the angles fighter pilot begins a maximum-performance turn to point at the target as quickly as possible. The segment of the maneuver between times "2" and "3" may be performed obliquely nose-low to provide a look-up shot at time "3," if such a shot is desired.

At time "2" in this maneuver, the angles fighter requires the airspeed that will maximize its average turn rate (i.e., minimize the time required) between that time and time "3." Although corner velocity yields maximum instantaneous turn rate, many fighters cannot sustain this speed for more than a very few degrees of turn. Usually for this reason a somewhat higher speed is desirable. The typical arc from time "2" to time "3" is about 135°, so the best speed at time "2" can be determined either by engineers or by experimentation as that initial speed which minimizes the time for a level turn of this magnitude. The optimum speed should be known by the fighter pilot for a representative combat weight, configuration, and altitude at full power. Generally, an increase in weight, drag, or altitude requires a higher initial speed.

Arriving at time "2" with optimum airspeed is not a simple matter, since speed at that point is dependent on initial velocity at the pass (time "I") and the maneuver between times "1" and "2." Because fighters can slow down more easily than they can accelerate during heavy maneuvering, it is normally advisable for the angles fighter to carry excess airspeed at the initial pass. If the bogey's turn rate cannot be matched between times "1" and "2" at this higher speed, a power reduction, speedbrakes, or a

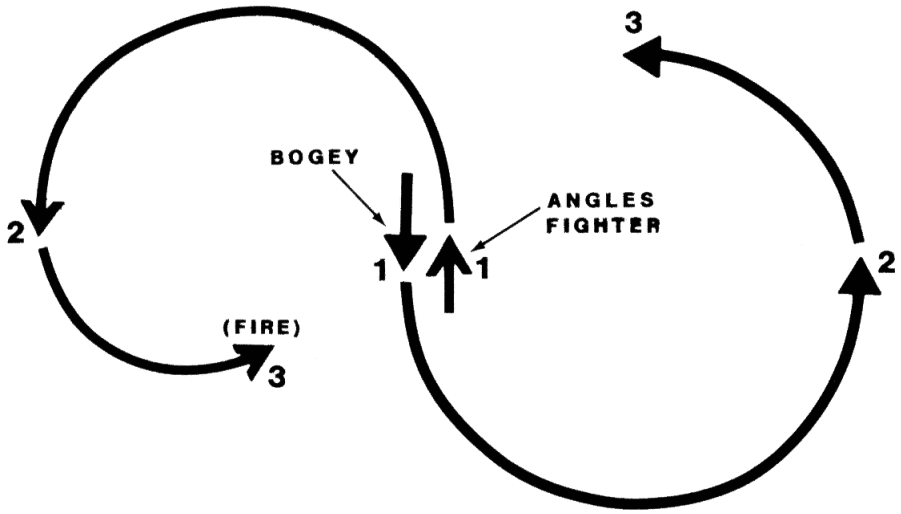


Figure 3-11. All-Aspect-Missile Separation Maneuver

climb can be employed to reduce speed and increase turn performance. It is essential that the angles fighter arrive at time "2" with at least neutral angles.

The choice of maneuver planes from time "2" to time "3" is largely dependent on the fighter's speed at time "2." Any excess speed should have been eliminated by this point, but sometimes hard bogey maneuvering results in the angles fighter arriving at time "2" with less than the desired airspeed. This deficit may be partially offset by a nose-low oblique turn, but a couple of cautions should be recognized. Any altitude differential generated by such a maneuver results in greater turn requirement for placing the nose on the target, delays the shot, and reduces aircraft separation. Another factor is the difficulty in maintaining the plane of maneuver. Just as the shortest distance between two points is a straight line, the shortest turn between times "2" and "3" is a constant-plane maneuver. When his aircraft is turning out of the target's maneuver plane, it is difficult for the pilot to predict the final plane of the attack at time "3," and therefore that maneuver plane cannot be established reliably at time "2." Any miscalculation results in greater required turn and reduced separation at the shot. Because of these complications it is usually best to keep the lift vector on the bogey throughout the maneuver from time "1" to time "3," regardless of the target's maneuver selection. At time "2" a small differential may be established in maneuver planes to compensate for lower than desired speed or to provide a bit of look-up for the shot.

The procedure just described typically provides aircraft separations of about two fighter turn radii. The actual separation at the shot is largely dependent on the level of bogey maneuver, however. If the opponent turns at his maximum capability throughout the engagement, and the angles fighter matches this performance as prescribed, separation will be minimal or nonexistent. Off-boresight capability is valuable for increasing launch separation in this maneuver, since the missile may be fired before the angles fighter completes the turn.

If the missile misses at time "3," the angles fighter could be at a considerable energy disadvantage, depending on the target's defensive maneuver. If the pilot of the angles fighter does not have an offensive position following such a missed shot, he should pass the bogey with minimum flight-path separation and then should commence a nose-to-tail extension maneuver to gain separation for escape. Returning to re-engage a bogey with all-aspect missile capability is not recommended.

Another viable angles tactic for all-aspect missiles involves the nose-to-nose technique described for other weapons scenarios, whereby the angles tactician attempts to gain a small angular advantage with each pass. Along with the angular gain on each turn, aircraft separation at the instant the target is boresighted also tends to increase during the nose-to-nose turn series. Once about 90° angular advantage has been achieved, aircraft separation at boresighting should be equivalent to about one fighter turn radius. This method is generally inferior to the nose-to-tail tactic, since it takes longer and usually generates less separation for the shot. It does,

however, facilitate maintaining sight of the opponent, since maximum separation is reduced, and it also makes bogey escape more difficult.

Whichever method is chosen, unless the weapon has a very short min-range requirement or the fighters have very large turn radii, separation for the shot is likely to be pushing min-range limits at the boresight point. If there are weapons system functions that must be accomplished prior to launch (such as radar acquisition, lock, and firing delays), some means must usually be found to complete these functions prior to the boresight point. Any delay after this time may result in a missed firing opportunity. With long min-range limits, small fighter turn radii, or unavoidable weapons-system delays, the angles tactician may be forced to use the more conventional angles tactics recommended for rear-quarter-limited weapons. If so, the full capability of the all-aspect missile may be usable in this scenario only in forward-quarter approach situations (prior to the first pass) or when the angles fighter begins the engagement with a position advantage.

*The Energy Fight*

The energy techniques described for the previous scenarios offer the opponent a temporary angular position advantage in exchange for a reduction in his airspeed. Although the nose-to-tail turn is ideal for this process, all-aspect missiles may render this tactic unusable because the greater aircraft separations involved may allow the opponent to satisfy his min-range requirements, as shown in Figure 3-11. Therefore, the energy tactician may be forced to use the less efficient nose-to-nose procedure (Figure 3-4). In some cases, even the separation allowed by this method may not be acceptable. While a forward-hemisphere gun shot can usually be defeated with a quick out-of-plane jink of very short duration, an all-aspect missile must be honored with a radical defensive maneuver that must be continued as long as the weapon appears to have even the most remote possibility of guidance. Such a maneuver almost invariably places the energy fighter in a defensive position and makes it highly vulnerable to a second shot by the bogey. In addition, once an adversary has a substantial position advantage (and this advantage must usually be allowed to ensure an adequate speed advantage for the energy fighter), the maximum-range and all-aspect capability of these weapons make escape by use of nose-to-tail extensions almost impossible for a similar fighter.

Assuming that the min-range capabilities of the missiles involved preclude shot opportunities during nose-to-nose turns, energy tactics may be a viable option in this scenario. As in the RQ missile scenario, the energy fighter's zoom maneuver may have to be modified to a climbing spiral, as shown in Figure 3-10. Because of the energy inefficiencies inherent in the nose-to-nose turns and the spiral zoom maneuver, it is difficult to gain sufficient height advantage against a similar fighter to avoid a vertical overshoot in the event of a missed shot. With all-aspect missiles, the pilot of the energy fighter cannot afford the luxury of a rolling scissors after such an overshoot, since the opponent could have a sizable angular advantage.

Instead, the energy tactician normally should attempt to escape after a missed shot by use of a nose-to-tail extension, as depicted in Figure 3-12. This can be done by diving toward the bogey's six o'clock position (time "2"), then beginning a gradual rolling pull-out while turning slightly in the nose-to-tail direction in an attempt to reach a heading approximately 180° from that of the bogey (time "3"). During the pull-out, care should be taken not to cross the bogey's tail, since this would encourage the bogey pilot to reverse his turn direction. If the bogey does reverse, the energy fighter must also reverse to reinitiate the nose-to-tail condition, and then continue the extension. The gradual pull-out is continued until the energy fighter reaches a shallow diving attitude, at which time the pilot should concentrate on accelerating rapidly to gain separation, while he turns only enough to keep the bogey in sight deep in the rear quarter. This diving acceleration should be continued to gain maximum speed at the lowest possible altitude to shrink the opponent's missile envelope. The extending pilot must attempt to keep the opponent in sight as long as possible and only turn back if a missile shot is observed within apparent range limits. This technique forces the bogey pilot to turn greater than 180° (after time "2") to place his aircraft's nose on the energy fighter, often providing sufficient time for separation beyond max-range limits.

*Comparison of Angles and Energy Tactics*

The firing opportunities offered by energy tactics usually involve look-down conditions. To the contrary, those presented to the opponent are more often look-up shots, more desirable for many weapons. Off-boresight weapons present even greater danger for an energy fighter. Considering all the hazards and disadvantages of energy tactics in this scenario, they are

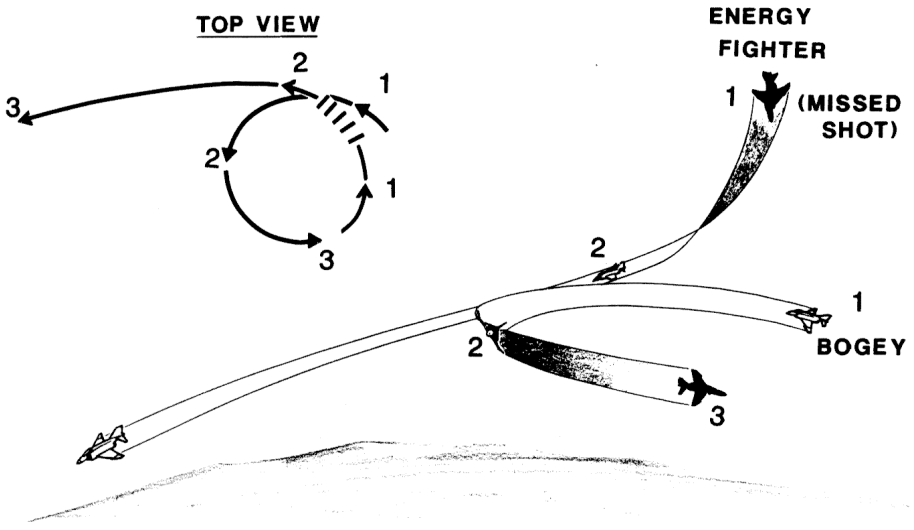


Figure 3-12. Disengagement Maneuver

not recommended, since angles tactics offer a much greater probability of success.

**Multiple-Weapons Scenarios**

Quite often, modern fighters are equipped with more than one class of weapon, most usually a gun in combination with either RQ or all-aspect missiles. This weapons situation forces the tactician to decide which envelope he wishes to satisfy; that is, which will be his primary weapon.

*Guns and Rear-Quarter Missiles*

As discussed in the RQ missile section, the gun snapshot envelope is considerably easier to satisfy once a fighter is engaged against a similar opponent. For this reason it is recommended that the gun be considered the primary weapon in this scenario, with the long-range capabilities of the missile serving to preclude the opponent's separation and escape.

Both the angles and the energy methods detailed in the guns-only section can be effective, with angles tactics probably preferable unless the pilot has extensive training in energy techniques. In many cases, relative advantage at the first pass will determine the best choice of tactics. Once the fighter has achieved a reasonable snapshot position, the bogey pilot must be concerned with maneuvering to defeat the opponent's weapon rather than with his aircraft, which usually leads to further offensive gains by the attacking fighter. After the fighter has a substantial position advantage, it becomes very difficult for the bogey to gain enough separation in an escape attempt to preclude a missile shot. Such a shot then forces the bogey pilot to turn hard back toward the attacker to defeat the missile, bringing him back into the attacker's gun range. This process continues until the bogey no longer has the energy to defeat the gun shot or to escape the missile.

*Guns and All-Aspect Missiles*

In this case the choice of the primary weapon largely depends on the quality of the missile in the maneuvering environment, or its "dogfight compatibility." A dogfight-compatible missile has a short min-range in relation to fighter turn radius (i.e., less than two turn radii against maneuvering targets in the forward quarter), little or no weapons system delay once the envelope is satisfied, and off-boresight capability that is usable in highly dynamic maneuvering situations. Such missiles are usually preferable to guns, primarily because of higher lethality. Unless the missile has at least two of these three qualities, however, the gun snapshot envelope may be easier to satisfy than the missile envelope. In this case the gun should be the primary weapon, and the missile can deter escape, as with the RQ weapon.

When the all-aspect missile is compatible with the maneuvering environment, it becomes the weapon of choice. Angles tactics should be employed in this case, preferably the nose-to-tail procedure illustrated in Figure 3-11. Regardless of whether this method or one of the nose-to-nose

techniques is chosen, a missile should be launched at the first opportunity, even if separation is marginal. Such a shot could be successful, but even if it is not, the target's defensive maneuver usually places it in a very vulnerable position for a follow-up gun shot.

**Dissimilar Weapons**

So far in this chapter it has been assumed that the opposing fighters have identical weapons. Although this is a very likely situation with similar aircraft, it does not always hold true. Supply problems, ordnance expenditure, or weapons system malfunction, for instance, quite conceivably could result in dissimilar weapon capabilities. In this section the more common weapons mixes are investigated.

*Guns versus Rear-Quarter Missiles*

Since the gun is a close-range weapon and the missile generally a longer-range weapon, it is to the advantage of the pilot of the guns-only fighter to remain as close to his missile-equipped opponent as possible. The angles tactics outlined in the guns-only section serve this purpose better than the energy methods described there. Since gun snapshot parameters are usually easier to satisfy than those of the RQ missile, the guns-only fighter may have some advantage in this scenario. The missile-equipped fighter, however, will have the better chance of safely disengaging from defensive situations. The gunfighter may have a more difficult time with separation, unless it disengages from a position of advantage.

For defensive purposes, on the other hand, the pilot of the missile fighter would like to maintain his speed and separation from the gunfighter. Energy tactics are ideal for this purpose. The pilot of the missile fighter therefore should attempt to deplete his opponent's energy, and then he should initiate a zoom maneuver to gain advantage.

In the case where the missile fighter is also gun equipped, its pilot should still employ energy tactics because of the added measure of safety inherent in greater speed, more separation from the opponent's weapon, and better disengagement opportunities. The gun, however, should be his primary weapon, since its parameters are easier to satisfy. The missile then becomes the means of preventing the opponent's escape.

*Guns versus All-Aspect Missiles*

Again in this scenario, the gunfighter pilot would like to stay close to his missile-equipped opponent to deny him min-range separation. Angles tactics and nose-to-nose maneuvers should be used exclusively for this purpose. If the missile-equipped fighter reverses at the pass to set up a nose-to-tail situation as depicted in Figure 3-11, the gunfighter pilot must make a rapid decision. His choices are to extend and disengage, continue in the nose-to-tail maneuver, or reverse to reinitiate a nose-to-nose condition. The best choice depends primarily on when the bogey reverses and on the capabilities of its weapons system in the maneuvering environment. The disengagement option is usually available if the pass occurs with high TCA and the gunfighter has good speed. By turning only far enough to keep

the bogey in sight, diving to low altitude, and accelerating to maximum speed, the gunfighter pilot usually can exceed missile max-range limits. The direction he happens to be heading at the time may have some bearing, since the pilot of the gunfighter may not wish to risk having to turn around and fly back past the missile fighter to return home.

Continuation of the nose-to-tail turn may also be an option for the gunfighter pilot in this situation. By turning at maximum rate, the gunfighter pilot normally can reduce separation to below min-range limits before the missile fighter can point at him. But when the bogey's weapon is highly compatible with the maneuvering environment (as defined previously), and particularly if it has a usable off-boresight capability, this can be a dangerous option. Even an immediate reversal by the gunfighter, reinitiating a nose-to-nose condition, may allow the opponent a shot with such a weapon. Disengagement may be the preferable option here.

A short delay in the missile fighter's reversal, or a second reversal, alters the situation considerably. Once it is well established in one turn direction, the gunfighter should disengage or continue in that direction, even if this results in a nose-to-tail condition. A delayed nose-to-nose turn by the gunfighter can generate a great amount of separation, allowing the missile fighter to meet its min-range requirements.

As for the missile-fighter tactics in this scenario, either angles or energy tactics are viable. The angles method of Figure 3-11 is probably preferable, since it is quicker, subjects the missile fighter to fewer snapshots by the gunfighter, and makes full use of the available all-aspect capability. Obviously, the missile fighter should shoot the bogey in the face prior to the first pass if possible.

Since the gunfighter pilot is likely to attempt a nose-to-nose maneuver at the pass, allowing him some lateral separation (up to about a quarter of a turn radius) may encourage a nose-to-tail turn instead, since a turn away might give the missile fighter angular advantage. Another ploy that may be useful in this situation is a "feint" turn. The pilot of the missile fighter can bank sharply toward the gunfighter approaching the pass, using top rudder to hold the nose level, but turning very little if at all. On seeing this, the gunfighter pilot is likely to turn away from the missile fighter to set up a nose-to-nose condition. In this case, just as the pass occurs and the missile fighter is out of sight on its opponent's belly-side, its pilot can reverse to establish a nose-to-tail turn, as desired. Quite often this tactic will result in the gunfighter pilot losing sight altogether. In any event, by the time he realizes the situation it is usually too late for the gunfighter pilot to reverse nose-to-nose without increasing separation even farther.

The pilot of the missile fighter may also use energy tactics in this scenario, since his opponent presents a reduced threat without a missile capability. The techniques involved are those described in the sections on guns only and rear-quarter missiles only. In this case, however, the missile fighter has the added possibility of forward-hemisphere shots from opposite positions in the rolling scissors. These are most likely to occur as the missile fighter comes over the top of its vertical maneuvers and points down at the gunfighter just starting up.

The foregoing discussion is relevant to other weapons mixes as well. For instance, if the gunfighter also has RQ missiles, tactics would remain essentially unchanged, but the missiles would tend to restrict the opponent's disengagement possibilities. Likewise, inclusion of guns and RQ missiles in the arsenal of the air-aspect missile fighter probably would not alter its pilot's tactics as long as his all-aspect weapon is dogfight compatible. With a less capable all-aspect missile, however, the gun may be the most effective weapon in this environment. Such a situation would bias optimum tactics in favor of those described in the guns-only section.

### Defensive Maneuvering

> If you think "Here is a master of . . . [tactics]," then you will surely lose.
>
> Miyamoto Musashi

All the scenarios considered to this point have assumed essentially equal starts, both in angles and in energy, for both fighters. Obviously this will not always be the case. When starting with an advantage on the opponent, the course of action is fairly simple: The advantage should be pressed, using either angles or energy tactics as appropriate, until the fight is won, the advantage is lost, or a disengagement is called for, possibly for fuel considerations. When one pilot recognizes he has an advantage and then he loses that advantage, he is losing the fight even though he and his opponent may still be neutral. This is the best time for him to realize that he is overmatched and immediately execute a "bugout" (escape). Once a trend is established in one-versus-one ACM, it is seldom reversed without a serious mistake on the part of the winning pilot. It is not healthy to bet all your marbles on an opponent's future mistakes. It is much wiser to admit that this guy may be the Red Baron, disengage while the opportunity still exists, and return another day, when he can be surprised and shot in the back. The days of white horses and chivalry went out with King Arthur.

> My system was to always attack the [enemy] at his disadvantage if possible, and if I were attacked at my disadvantage I usually broke off the combat, for in my opinion the [Germans] in the air must be beaten at [their] own game, which is cunning. I think that the correct way to wage war is to down as many as possible of the enemy at the least risk, expense and casualties to one's own side. ... I hate to shoot a [victim) down without him seeing me, for although this method is in accordance with my doctrine, it is against what little sporting instincts I have left. ... At the same time, when one is taken at his advantage and one has to fight, one always has ... to fight him like anything, for, as far as fighting the [Germans! in the air is concerned, nothing succeeds like boldness, and the [enemy] is usually taken aback when boldness is displayed.[2]
>
> Major James T. B. McCudden, RAF
> 57 Victories, WW-I

Although no true fighter pilot will admit it, it is also possible to start a fight at a disadvantage, or to find yourself in such a predicament during an engagement. This is the situation that "separates the men from the boys," and it calls for the greatest possible skill and cunning.

After a pilot recognizes that he is at a disadvantage (and the successful fighter pilot must be able to recognize this situation), he must assess the type and magnitude of that disadvantage. An angular advantage is pretty easy to see: The fighter that has its nose pointed closer to its opponent has the angular advantage. The magnitude of this advantage is simply the difference in the turns required by each fighter to point at the other. As explained earlier, the magnitude of this angular advantage is most easily assessed when one fighter is pointing directly at the other (its AON equals zero), since that leaves only one angle to estimate.

An energy advantage can be much more difficult to recognize and assess than an angular advantage. An energy advantage can be in the form of excess speed, altitude, or both. An altitude advantage is easy to see, but determining a total energy advantage can be difficult because of possible speed differences between fighters. Particularly in slow-speed situations, however, the higher aircraft must be assumed to have an energy margin unless the pilot of the lower fighter has some reason to believe his aircraft is significantly faster. Speed differences can be very difficult to determine. Probably the most effective method of assessment is for the pilot to observe the bogey's maneuvers in relation to his own, as explained in conjunction with energy tactics. With similar aircraft, the one that turns hardest bleeds the most airspeed, etc. When the fighters are below corner speed, instantaneous turn rate can be a good indication, since the faster fighter will generally turn faster. Nose-to-nose turns provide perhaps the best measure of relative speed. In this situation, unless one fighter has a significant angular advantage, a faster opponent will appear to move forward along the horizon, and vice versa. In addition, when similar fighters are maneuvering at near their maximum capabilities, the slower one will normally remain inside the flight path of the faster aircraft in nose-to-nose turns.

Unfortunately, when he is taken by surprise, the pilot may not have the luxury of making a safe, quick energy comparison. Probably the surest method is an immediate zoom climb to zero airspeed. Then, assuming the bogey does likewise, the fighter that tops out highest has the most energy (i.e., all energy is converted to altitude, where differences are readily apparent). A zooming contest is not wise, however, if a pilot is unsure of his relative energy state, since he will be in serious trouble at the top if he falls off first.

> A MiG at your six is better than no MiG at all.
>
> Unknown U.S. Fighter Pilot

### *Maneuvering with an Angular Disadvantage*

The first point for a pilot to remember when he is at a disadvantage of any kind is to avoid panicking. It's never too late for a fighter pilot until he's dead, and then he won't care anyway. Very few good moves are generated in panic, so careful, deliberate maneuvering is in order. Secondly, the defensive pilot should not attempt to go directly from the defense to the offense. The first goal should be to regain neutrality without being shot. At

that point the pilot can decide to terminate the engagement and escape, or to continue from a neutral position as discussed in detail previously. Too often the overeager pilot will expend excessive energy in a maximum effort to go from angular defensive to angular offensive, only to discover that he is now energy defensive and cannot maintain his angular advantage.

There is wide range in the degree of angular disadvantage, from almost neutral to weapons in the air. The situation needs to be evaluated instantaneously and only the necessary reaction made. A break turn is wasteful when a hard turn will suffice.

Starting with the easiest situation first, when a bogey with an angular advantage is detected in the forward hemisphere, the reaction depends largely on the range and the weapons involved. If the enemy is gun equipped but is outside firing range or lacks proper lead, an in-plane turn is called for. This turn should be hard enough to pull the bogey to the nose by the time maximum effective firing range is reached, so that the defender has an equal firing opportunity. If the bogey has already satisfied snapshot parameters, a guns defense is in order. The techniques involved here have already been discussed in detail. Should the bogey's initial angular advantage be judged too great for the defender to meet the attacker head-on, but guns parameters have not yet been satisfied, the defender can perform an in-plane turn just hard enough to stabilize the angular situation and watch for the opponent's next move. If the attacker begins to satisfy guns parameters (i.e., pulls lead as he closes), the defender can start guns-defense maneuvering. The attacker's other likely responses are to drift toward a lag-pursuit position or to initiate an out-of-plane maneuver, such as a high yo-yo or barrel-roll attack. In either case the immediate danger has passed, and the defender can begin to work toward regaining angular neutrality.

If the attacker chooses lag pursuit, the defender should continue to pull toward him just hard enough to prevent the bogey from reaching the blind spot at six o'clock. In some cases this may require using max-G and a shallow nose-low turn to maintain speed and turn rate. If it becomes obvious, however, that such a nose-low turn must be steeper than 10° to 15° in order to maintain sight, a quick turn reversal is usually the best move. A reversal can be dangerous against a gun-equipped bogey with an angular advantage, as explained previously, but it is normally preferable to losing sight or giving the opponent an excess altitude advantage at this point. If a reversal is executed it should be level or slightly nose-low. A nose-high reversal often results in a zooming contest or a rolling scissors, neither of which is recommended until the defender has had a chance to evaluate the bogey's energy. After the reversal the defender should try to meet the bogey head-on to neutralize its angular advantage. Normally the defender should remain level with or below the opponent, at or below corner speed, during this nose-to-nose turn. Angles tactics are appropriate here since the defender's goal is to gain angles, from defensive to neutral. Altitude differential should be limited to about a quarter-turn-radius equivalent, however, even if several repetitions of this process are required to neutralize the opponent's advantage completely.

Returning to the initial defensive turn, if sight can be maintained in a level or slightly nose-low nose-to-tail turn, this maneuver should be continued as hard as necessary until there is no longer any danger of the bogey reaching the blind spot. At this point the defender might continue a nose-to-tail extension maneuver and escape. If this is not practical, he should initiate a low yo-yo, pulling hard enough to make a definite gain in angles evident (i.e., bogey moves forward along the canopy). This rate of angular gain should be adjusted so that the defender will meet the bogey head-on at the next pass.

If the opponent's response to the initial defensive turn is an out-of-plane maneuver, the immediate pressure is once again taken off the defender. When maneuvering out-of-plane the attacker is no longer gaining angles, so the defensive turn should be terminated quickly and a nose-low unloaded extension commenced. The defender should maintain his original bank angle, however, to avoid revealing his intentions to the opponent. This extension maneuver gains both energy and separation for the defender which can later be traded for angles. Once the attacker's climb angle peaks and he begins to pull in-plane again, the defender needs to decide whether he has enough separation to make a safe escape. If so, this is probably the prudent move. One mistake has already been made in allowing the opponent to gain the initial offensive; another error could easily be fatal. Assuming an escape is not practical, however, the defender should pull back into the attacker in the closest direction, keeping the lift vector on or slightly below the bogey. This technique ensures that the defender will meet the bogey level or slightly below. Once again, altitude differential should be limited to about a quarter of a turn radius. This turn should be just hard enough to take away the opponent's angular advantage in the horizontal plane, and it should be completed with the minimum necessary altitude differential. If this cannot be achieved on the first attempt, the defender can repeat the entire process again, this time probably starting at less angular disadvantage, until neutrality can be achieved.

When an attacker begins with a large angular advantage on the defender, possibly greater than 90°, the initial defensive reaction is again dependent on the enemy's weapons and his range. It might be possible, for instance, to outrun a guns-only bogey in the rear hemisphere, depending on relative speeds and closure. Such a large angular advantage, however, often places the attacker very near his firing parameters, so defense against his weapons is normally first priority. For guns this is a hard in-plane turn toward the bogey until it approaches firing parameters, then some sort of out-of-plane maneuver to spoil the attacker's aim. When the attacker is expected to have missile armament, an in-plane break turn should be started toward the threat (a missile may already be on the way), keeping the lift vector slightly below the bogey. This technique should quickly begin reducing the attacker's angular advantage, possibly holding him outside RQ missile parameters, while generating a look-down situation for the bogey's missile and maintaining speed for a subsequent missile-defense maneuver. If at any point a missile comes off the rail, the defender must immediately

begin missile-defense tactics as discussed earlier. Unless a missile is in the air, the initial break turn is usually continued until the bogey's advantage is reduced to about 90°, then it can be relaxed to stabilize the situation while reducing energy bleed. An exception to this rule might arise when an attacker is equipped with all-aspect heat seekers, in which case the break turn might be continued until the bogey penetrates min-range.

Once he is inside missile min-range or outside angular parameters, the gun-equipped attacker can either continue to press for a shot, begin to lag, or start an out-of-plane maneuver, as before. In the first case a guns-defense maneuver should be performed at the appropriate time. An attempt by the attacker at a high-deflection gun shot will usually lead to an overshoot with high closure and little nose-tail separation—the ideal set-up for the defender to perform a nose-to-nose reversal. Again, such a reversal should be made level or slightly nose-low in an attempt to force a flat scissors. This maneuver should be to the defender's advantage, since he is likely to be at slower speed and inside the attacker's turn radius. If the bogey begins a rolling scissors or a zoom after the overshoot, the defender should normally attempt a diving, nose-to-tail extension to escape, unless he is missile equipped and able to meet firing parameters quickly. Going vertical with the bogey is usually not wise, since the attacker is likely to have greater energy.

If the attacker chooses the lag option, a level or slightly nose-low turn should be continued in an attempt to reduce the attacker's advantage to about 90° or less as he crosses six o'clock. With such a high TCA it is unlikely that the defender will be able to maintain sight of the bogey in a continued nose-to-tail turn, however, so a reversal should be started as the attacker crosses six. This hard nose-low, nose-to-nose turn should be made at or below corner speed in an attempt to reduce the bogey's angular advantage as much as possible by the next pass while limiting altitude differential to about a quarter of a turn radius. A guns-defense maneuver may be required at the next meeting, but the attacker should have only a forward-hemisphere snapshot. After the second pass the defender can revert to the techniques outlined earlier in this section for defending against opponents with a smaller angular advantage.

An attacker who selects an out-of-plane repositioning maneuver on the first pass can be countered as though he had less angular advantage, i.e., with an unloaded extension. In this case, however, the attacker's out-of-plane maneuver is likely not to be so radical, allowing less extension time and forcing the defender to come back sooner. The same come-back technique as before is still appropriate; namely, make a hard turn in the closest direction holding the lift vector on or slightly below the bogey. This should reduce the attacker's angular advantage at the next pass, and the cycle can be repeated, depending on the attacker's reaction.

After the first pass, essentially the same defensive techniques apply regardless of the attacker's weapons. Defensive turn reversals, however, are much safer against bogeys without guns, and escape is more difficult from a missile-equipped enemy.

In addition to an initial angular bite, the opponent may also have an

energy advantage. In general, the angular disparity should be corrected first, since this is normally the more dangerous of the two. After drawing neutral on angles it is much easier to redress the energy balance.

*Maneuvering with an Energy Disadvantage*

At the beginning of an engagement the pilot may suspect that the enemy has an energy advantage, with or without an angular advantage. Also, if he has had to regain angular parity, the defender must assume that he is at an energy disadvantage. After all, energy bleed has probably been necessary to nullify the attacker's initial angular advantage. With this in mind, the defender's next goal is either to escape, an option that is often available from a neutral angular position, or to regain energy parity. Even though the trend may have been in the defender's favor, he must recognize that he is still at a disadvantage, so escaping to return another day is certainly an honorable choice. On the other hand, the opponent has failed to capitalize on any initial angular advantage, and the only way to win with an energy advantage alone is to run the opponent into the ground. Therefore, the defender has reason to be positive about his chances of success at this point.

Just as recovery from an angles disadvantage requires angles tactics, correcting an energy deficit calls for energy tactics. The nose-to-nose turn is the defender's primary tool for bleeding the energy of a faster opponent. When two fighters meet essentially head-on and perform co-planar nose-to-nose turns, it is the fighter with the smaller turn radius that gains advantage at the next pass. In order to match turn radius, a faster fighter must pull substantially more G and bleed energy at a much faster rate than a slower opponent. Figure 3-13 illustrates an example of this process.

At time "1" in this example the fighters meet nearly head-on and about co-altitude, but the bogey is substantially faster. At the pass, assuming the defender wants to engage, he checks the bogey's direction of turn and quickly begins a level sustained turn in the nose-to-nose direction. The bogey's greater airspeed results in its having a larger turn radius than that

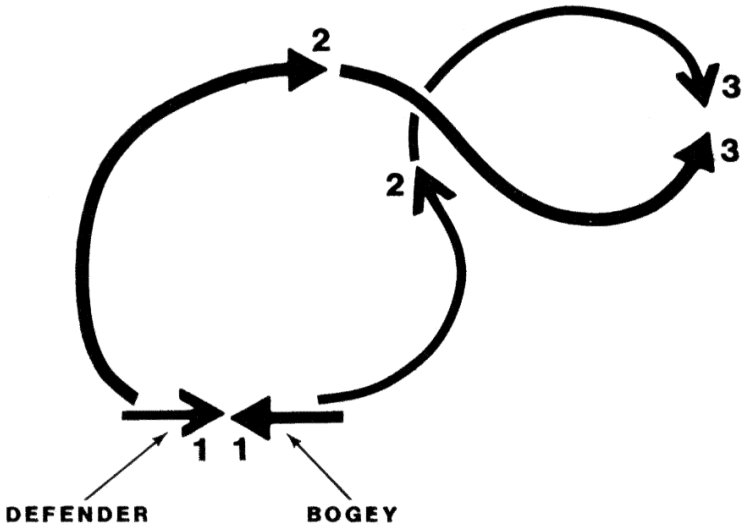


Figure 3-13. Maneuvering with a Speed Deficit

of the defending fighter, so the bogey is forced to pull harder in order to limit the defender's angular gain at the next pass. Meanwhile the defender just maintains his sustained turn and reverses at time "2," taking whatever angular advantage the bogey allows, and possibly attempting a gun snapshot. In this case the bogey has turned hard, taking away most of the defender's angular advantage, but consequently bleeding excess airspeed while the defender has been maintaining speed. After this second pass the bogey pilot reverses to maintain sight, generating another nose-to-nose turn. The defending fighter simply continues its sustained turn. Approaching the third pass, time "3," the defender's angular gain has not increased noticeably since the previous pass. This is an indication that the two aircraft are now approximately co-speed. The defending fighter has succeeded in neutralizing the bogey's energy advantage while maintaining, or possibly even gaining, angles. The defending pilot can now continue with either angles or energy tactics as he chooses, from a neutral start.

Returning to time "2" in the previous example, what if the bogey pilot refused to reverse his turn at this point, but instead continued to the right, nose-to-tail? In this case, because of its angular advantage at the pass, the defending fighter is still at an advantage. First of all there is a good chance that the bogey pilot could lose sight during this turn. Secondly, the bogey must turn farther than the defending fighter to generate a head-on pass at the next meeting, giving the defender another excellent escape opportunity. Because slower speed does not offer the defender an inherent advantage under nose-to-tail conditions, he should take this opportunity to accelerate. The nose-to-tail turn should be continued (assuming the defender chooses to remain engaged), but only hard enough to ensure a head-on meeting at the next pass. In doing so the defender trades his angular advantage at time "2" for additional speed, while the attacker must turn farther, leaving him with little chance to build energy. At the next pass, if the defender is still unsure of his relative energy, the nose-to-nose technique can be tried again. If the defending fighter is able to accelerate up to its best sustained-turn-rate speed, however, it is time to begin offensive angles or energy tactics.

An even more efficient technique for this situation (i.e., continued bogey nose-to-tail turn at time "2") from an energy standpoint is an unloaded acceleration just after the pass (time "2") until the bogey has regained the angles lost in the first nose-to-nose turn. When the bogey reaches a heading exactly opposite that of the defender, the defender can resume his sustained nose-to-tail turn at his new higher airspeed. Either of these techniques can be dangerous against an all-aspect-missile-equipped opponent, however, since he still may be able to bring his nose to bear first, with sufficient separation to satisfy his min-range parameters.

The techniques outlined in conjunction with Figure 3-13 should work well against a bogey that remains roughly co-altitude, but what if it has a substantial altitude advantage at the first pass, or climbs steeply during the engagement? The general rule here is to work below the bogey, make it come down to engage, and try to confine the fight to the horizontal plane. A higher-energy opponent with an altitude advantage can be either faster

or slower than the defender, and it may not be readily apparent which is the case. Since the nose-to-nose turn technique just described is predicated on the defender having a smaller turn radius, it may not be effective against a higher, slower opponent. One means of correcting this situation is for the defender to climb up toward the bogey, either approaching the first pass or during the first turn, allowing speed to bleed down to the range for minimum sustained turn radius. For most jet fighters under normal combat conditions this speed will be roughly 1.5 times power-on stall speed for its weight, configuration, power, and altitude (usually somewhat slower for prop fighters). This speed will vary somewhat among different fighter types, and it is often faster at very high altitudes, so performance charts should be consulted. In general, use of any configuration (e.g., flaps, slats) which lowers power-on stall speed is advantageous for this tactic. If they are employed, however, use of any devices that increase unloaded drag or decrease forward thrust should be discontinued before periods of acceleration. By operating in this speed range, the defender can be assured that a similar bogey cannot outperform him in nose-to-nose turns regardless of the opponent's speed. The nose-to-nose turn tactic should then allow the defender to put angular pressure on the attacker, forcing him to expend his energy advantage in response.

It must be cautioned, however, that minimum sustained-turn-radius speed will be well below corner speed for the defender, and this may not be a healthy co-.idition in a hostile combat environment where the possibility of SAMs or additional threat fighters exists. In addition, if after the defender climbs to obtain optimum maneuvering speed the bogey still has a substantial altitude advantage, the attacker may be able to make an overhead attack and force a weapons-defense maneuver. Such a defense may be difficult at slow speed.

As an alternative to this tactic, the defender can maintain speed and altitude and perform a sustained nose-to-tail turn instead. In response to this move the bogey is likely to make a nose-low turn, possibly gaining some angles by the next pass, but expending some of its energy margin in the process. Once the altitude advantage is reduced, the defender can return to the nose-to-nose technique or to the previously described tactics appropriate for opponents with speed or angles advantage.

An opponent who maneuvers vertically or steeply oblique after a head-on pass may be able to use his vertical geometry to offset the defender's smaller turn radius in level nose-to-nose turns. This may enable the bogey pilot to maintain his energy advantage while making repeated attacks on the defender. The response to this tactic is much like that recommended against the high yo-yo; namely, an unloaded acceleration after the pass until the bogey's climb angle peaks, then a hard come-back in the closest direction, keeping the lift vector on or slightly below the bogey. This technique should limit the bogey's angular gains while forcing the attacker to expend his energy advantage. An all-aspect-missile-equipped opponent may be able to satisfy firing parameters with such vertical maneuvers, so the defender may prefer an escape attempt immediately if the bogey zooms. A shot from well above the target, however, may be severely

limited by look-down as well as marginal with respect to min-range, and the defender should be well positioned for a defensive maneuver. Whenever meeting the bogey from well below, as may be the case after a maneuver such as that just described, the defender should normally make every effort to reduce the opponent's vertical separation just prior to the pass. A zoom climb to within about a quarter of a turn radius of the bogey's altitude at the pass should limit the attacker's opportunity for a lead turn and an effective overhead attack.

## Summary

In the similar-aircraft, one-versus-one environment, pilot ability is the single most critical factor in determining success or failure. Tactics are selected primarily on the basis of the available weapons capabilities of the opponents, and they are designed to optimize aircraft performance to achieve firing parameters before the adversary reaches his parameters. Depending on the initial conditions and weapons mixes, either angles or energy tactics may be preferable. Victory depends on having a tactical plan prior to the engagement and executing that plan aggressively.

> The aggressive spirit, the offensive, is the chief thing everywhere in war, and the air is no exception.
>
> Baron Manfred von Richthofen

## Notes

1. Robert S. lohnson, *Thunderbolt!* p. 204.
2. James T. B. McCudden, *Flying Fury,* pp. 264, 280.