4

One-versus-One Maneuvering, Dissimilar Aircraft

Dissimilar fighters are fighters that have some performance characteristics which differ from those of the opponent by more than about 10 percent. The performance measures of most interest are turn performance (both instantaneous and sustained) and energy performance (climb, acceleration, and speed). Of course there are many other ways in which fighters may differ (e.g., roll and pitch performance, size, pilot visibility limits, combat endurance, and radar capabilities). The influence of some of these factors is also discussed when appropriate.

As explained in the Appendix, instantaneous turn performance is determined primarily by the ratio of aerodynamic lift to aircraft weight at low speeds (i.e., below corner velocity) and by the ratio of structural strength to aircraft weight at high speeds. Except in cases of extreme disparity in structural strength between fighters (i.e., on the order of a 50 percent advantage in maximum structural G for one aircraft), this limit is not usually as important in air combat as the aerodynamic limit. When a fighter pilot finds himself in a serious defensive situation, and to some extent when he is very near a lethal offensive position, he will use whatever G is required to save himself or to get the shot. A few popped rivets or some wrinkled skin is a small price to pay for the pilot's life or for a downed enemy aircraft. Since World War I there have been very few instances when a pilot has actually pulled the wings off his own fighter. Limits of structural strength must be adhered to in peacetime, however, since overstresses result in additional maintenance time, expense, and lost training. Therefore, ways must be found of winning within the design limits of the aircraft.

The relative low-speed instantaneous-turn-performance capabilities of two fighters can be determined by comparing their velocity-load factor (V-n) diagrams (see the Appendix). The aircraft with the greatest usable G capability at a given speed has superior instantaneous turn performance (i.e., faster turn rate and smaller radius) at that speed. This G capability reflects the maximum lift-to-weight ratio of the fighter, which depends to a great extent on the ratio of aircraft weight to total wing area, commonly called the "wing loading." As explained in the Appendix, wing loading alone can be misleading in this regard if one fighter has a more efficient wing for producing lift, possibly as a result of maneuvering slats or flaps. The way in which wing loading is calculated provides a further complication, as illustrated in Figure 4-1. The wing loading of the F-14 fighter shown here might be stated conventionally as 97 lbs/sq ft, based on the shaded area in the left-hand silhouette. The very broad fuselage of this aircraft, however, provides a large proportion of the total lift, particularly at very high AOA, so a more realistic value of wing loading (54 lbs/sq ft) might be based on the area shaded in the right-hand silhouette.

Because of these complications it will be necessary to make some assumptions to simplify maneuver discussions. Therefore, the term *low wing loaded* is assumed to denote superior instantaneous turn performance and slower minimum speed.

Sustained turn performance is a little more complex. The Appendix explains that sustained-G capability is the result of a fighter's thrust-to-weight ratio (T/W) in combination with its aerodynamic efficiency, which may be expressed as its lift-to-drag ratio (L/D) at the particular maneuvering conditions. But G alone does not make turn performance, as turn rate and radius are also dependent on airspeed. Lower airspeed at a given G level improves both turn rate and turn radius. All else being equal, low-wing-loaded aircraft tend to achieve their best sustained G at a lower speed, and therefore they often have a sustained-turn advantage. It is possible, however, for a high-wing-loaded fighter to have better sustained turn rate at a higher airspeed by sustaining much greater G, which, in the case of aerodynamically similar aircraft, could be achieved with greater T/W. Sustained turn radius, however, is such a strong function of airspeed that the low-wing-loaded fighter nearly always has the advantage here, regardless of T/W. In this chapter a low-wing-loaded fighter is assumed, unless other-

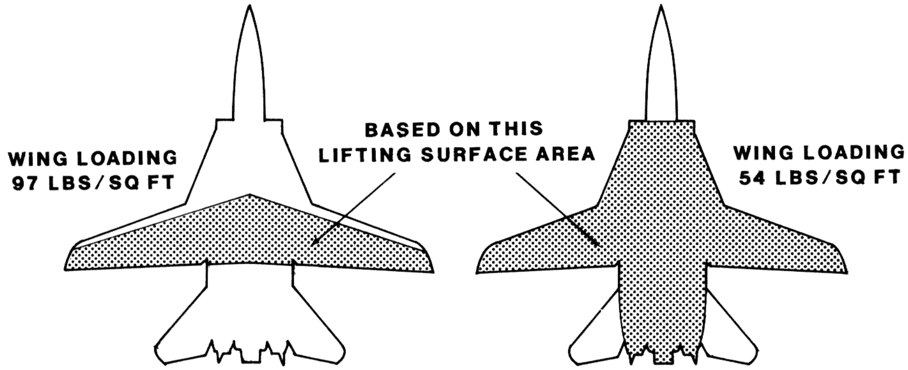

Figure 4-1. Calculation of Wing Loading

wise stated, to have an equal or better sustained turn rate and a tighter sustained turn radius than its high-wing-loaded opponent.

Energy performance reflects a fighter's P_S under specified flight conditions. P_S at a given airspeed is a function of the ratio of excess thrust to aircraft weight, as shown by Equation 4 in the Appendix, and is a measure of the aircraft's ability to climb or accelerate under those conditions. A fighter's T/W is a fairly good indicator of its energy performance. This ratio is usually stated in terms of static sea-level thrust and a representative combat weight. For piston-engine aircraft a parameter known as "power loading," the ratio of aircraft weight to brake horsepower (normally maximum sea-level power), is used rather than T/W. Both these measures may be misleading, however, since operating conditions of altitude and airspeed can affect two fighters in different ways. For example, a fighter with a relatively powerful normally aspirated piston engine may have lower power loading and better performance than a turbocharged fighter at low altitudes; but the turbocharged fighter would retain its power better at altitude and could have superior energy performance at higher levels. Likewise with jet engines, performance can vary greatly with inlet design, therefore a fighter may have higher T/W and better performance at slow speeds but be inferior at faster speeds.

A fighter's aerodynamic efficiency, in particular its lift-to-drag ratio, is also vitally important to energy performance, especially at high G or high speed. In order to simplify this discussion, however, the term *high T/W* infers greater climb rate, faster acceleration, and higher maximum speed capability relative to the opponent.

Obviously fighter performance can be a complex subject, and the numbers alone don't always tell the whole story. Development of effective tactics against dissimilar aircraft is, however, highly dependent on intimate knowledge of all aspects of relative fighter performance and design, as well as total familiarity by the pilot with his own aircraft and weapons system. Comparison testing, in which enemy aircraft are flown against friendly fighters, is undeniably the best method of gathering this crucial information.

> One of our achievements at this period was the "Rosarius Traveling Circus." This was a flight comprised of all air-worthy captured planes we could find. They traveled through the West from unit to unit in order to familiarize our pilots with enemy technique. The leaders could fly these enemy types themselves. In this way we found out that we had usually overrated their performance. The circus proved a great success.
>
> Lt. General Adolph Calland, Luftwaffe

Low Wing Loading versus High Thrust-to-Weight

Encounters between a low-wing-loaded fighter and an enemy fighter with greater T/W are quite common. In this case each fighter has performance advantages and disadvantages relative to its opponent. The engagement strategy is for the pilot to exploit the opponent's most serious weaknesses while taking full advantage of his own fighter's greatest strengths.

The low-wing-loaded fighter's greatest performance advantages are assumed to be good instantaneous turn performance, slow minimum speed, and a tight sustained turn radius. In some cases this aircraft also might have a significant sustained-turn-rate advantage. Its weaknesses include inferior climb and acceleration performance under low-G conditions, and slower "top-end" speed.

These characteristics are ideally suited to the use of angles tactics as described in the last chapter. One of the problems of the pilot of a low-wing-loaded fighter is how to get close to an opponent who has greater speed capability. This may be accomplished with geometry by use of pure and lead pursuit. High and low yo-yos and barrel-roll attacks also may be useful. Since the high-T/W opponent has better climb capability and vertical potential, the pilot of the low-wing-loaded fighter should attempt to constrain the fight to the horizontal plane as much as possible. Nose-to-nose turns make best use of a turn-radius advantage, and lead turns can be devastating because of instantaneous-turn superiority. A flat scissors should be lethal to the high-T/W fighter since it suffers from both a turn-performance and a minimum-speed disadvantage. The low-wing-loaded aircraft might also have some advantage in a rolling scissors because of better slow-speed controllability, but usually not so great an advantage as in the flat scissors. In cases where the high-T/W enemy has a sustained-turn-rate advantage, the rolling scissors generally should be avoided.

On the other hand, the pilot of a high-T/W fighter should concentrate on energy tactics when he is engaging a low-wing-loaded opponent. Lag pursuit and vertical/oblique maneuvers are necessary ingredients. Nose-to-tail geometry is usually preferable because of the assumed disparity in turn radii.

The defensive spiral might be handy if the pilot of the high-T/W fighter finds himself at a serious disadvantage. A high-wing-loaded aircraft often can generate much greater induced drag than a low-wing-loaded adversary, which may lead to a rapid vertical overshoot and subsequent position advantage for the high-T/W fighter. If this advantage cannot be capitalized on quickly, however, the low-wing-loaded bogey may use its superior low-speed turn performance to shallow out its spiral and regain the upper hand as the maneuver continues.

The Angles Fight: Guns Only

The angles tactics recommended in the similar-aircraft guns-only scenario are almost all relevant to the low-wing-loaded fighter in this case. There are a few slight differences in detail, however. For instance, in the similar-aircraft case each fighter attempted to gain an energy advantage over the other by climbing or accelerating before the first pass. In this case the bogey's higher T/W may allow it to win this preengagement race and achieve a speed and/or height advantage. To reduce this factor to a minimum, the pilot of the angles fighter might choose to cruise at an altitude well above that at which bogeys might be expected, so that his initial height advantage may offset the bogey's preengagement performance and provide the low-T/W fighter with an energy advantage, or at least make it nearly equal in energy to the high-T/W fighter at the beginning of the fight. Since the low-wing-loaded fighter is likely to have lower maximum speed capability, some height advantage is desirable at the pass to help ensure energy parity. Practical considerations such as visibility and weapons-system performance, however, may prevent use of this technique.

Another consideration is the performance superiority of the low-wing-loaded fighter at slow speeds. For example, its best climb speed, best sustained-turn speeds, and minimum vertical-maneuvering speed all are probably lower than those of its high-wing-loaded adversary. This slow-speed efficiency improves relative performance in nose-to-nose turn situations. The angles fighter also may have some sustained-turn-rate advantage, which would enable it to make angular gains in nose-to-tail turns with little relative energy sacrifice, but this process would be very slow and is definitely inferior to the nose-to-nose technique.

> On individual combat tactics, aggressiveness is the keynote of success. ... The enemy on the defensive gives you the advantage, as he is trying to evade you, and not to shoot you down.
>
> Major Thomas B. "Tommy" McGuire, USAAF

In approaching the initial pass, the angles fighter should attempt to generate some flight-path separation for a lead turn, as shown in Figure 3-1. Turn-performance superiority should provide the low-wing-loaded fighter with some angular advantage at the pass. If the bogey continues straight ahead or turns away from the attack to set up a nose-to-nose condition, the angles fighter should continue in the original turn direction. Should the bogey turn toward the attack, however, a turn reversal is called for, as depicted in Figure 3-1. Since the pilot of the low-wing-loaded fighter does not have to optimize his turn performance to gain an advantage on the opponent, best sustained-turn-rate speed, rather than corner velocity, is normally the best engagement airspeed. Because energy is so critical for this fighter, the pilot should maneuver only as hard as necessary. Quite often small angular gains can be made in nose-to-nose situations simply by using level sustained turns.

> This should be an initial attack which on the surface is very forceful and fast, but which leaves you some reserve. Do not spend all your energy on your first attack.
>
> Miyamoto Musashi

The rest of the angles-fight sequence shown in Figures 3-1, 3-2, and 3-3, and the discussion of these figures, applies here, as well. The high-T/W fighter may, however, achieve higher zoom-altitude advantage, preventing the angles fighter from threatening a gun shot at time "5" of Figure 3-2. In this case the tactic of hiding beneath the bogey, as shown in Figure 3-7, may be useful. Instantaneous turn performance should give the pilot of the angles fighter a sweeter snapshot, or even a tracking shot in the end-game (Figure 3-3).

If the shot is missed, the bogey can usually dive away and escape even easier than it could in the similar-aircraft case, since it now has higher acceleration and max-speed performance. If the bogey pilot decides to stay and fight by pulling back up steeply vertical, however, the pilot of the angles fighter should ensure he has minimum vertical-maneuvering speed before following the bogey up. Such a maneuver should result either in a repeat of the sequence of Figure 3-2 or in a rolling scissors. In the latter case the low-wing-loaded fighter normally has an advantage because of better slow-speed controllability.

Throughout the fight, the pilot of the angles fighter can be somewhat less concerned with overshoots than he would be in the case of similar fighters, since the bogey's larger turn radius and higher speed make it more difficult for its pilot to gain advantage after an overshoot by the angles fighter. Gross vertical overshoots still should be avoided, however, since they may allow the bogey at least a temporary advantage, and possibly a snapshot, after one turn of a rolling scissors. Minimum vertical-maneuvering speed should be observed whenever the angles fighter is in close proximity with the bogey to guard against zoom maneuvers. Greed is the angles fighter pilot's greatest enemy. He should avoid trying to grab angles faster than his aircraft's performance permits. Once further angular gains can no longer be made at speeds greater than that required for vertical maneuvering, the high-wing-loaded fighter must have bled its speed down to or below that of the angles fighter, so the bogey should have little vertical potential remaining. In this case the pilot of the angles fighter can safely bleed to slower speeds and finish off his opponent.

> Don't let the [enemy] trick you into pulling up or turning until you lose your speed.
>
> Major Thomas B. "Tommy" McGuire, USAAF

In the case of dissimilar fighters, the high-wing-loaded bogey pilot is less likely to allow the angles fighter the advantages of nose-to-nose geometry. By being uncooperative, the bogey pilot can make things more difficult. For` instance, he may choose to reverse his turn direction after the first pass, reinitiating a nose-to-tail condition, as shown in Figure 4-2.

The reaction (reversal) of the pilot of the high-T/W bogey depicted here is likely to occur at some time after the first pass, when he observes the angles fighter's nose-to-nose reversal. A reversal at this time requires the bogey pilot to "kick his opponent across the tail" and usually results in a protracted blind period when the angles fighter is out of sight. Such a maneuver performed well after the pass may cause the bogey pilot to lose sight of the angles fighter altogether, particularly when small, high-speed fighters are involved, so it is not without risk. The pilot of the angles fighter can increase his chances of being lost at this point by making a radical change in his maneuver plane (i.e., zooming or diving). Figure 4-3 shows one possible mid-game approach in this situation.

In this top view the fighters are initially positioned at time "3" as in Figure 4-2. Because of the bogey's late reversal and the low-wing-loaded fighter's better turn performance, the angles fighter already has a significant angular advantage at this point, but it is probably well outside effective guns range. The task of the angles fighter pilot in this nose-to-tail

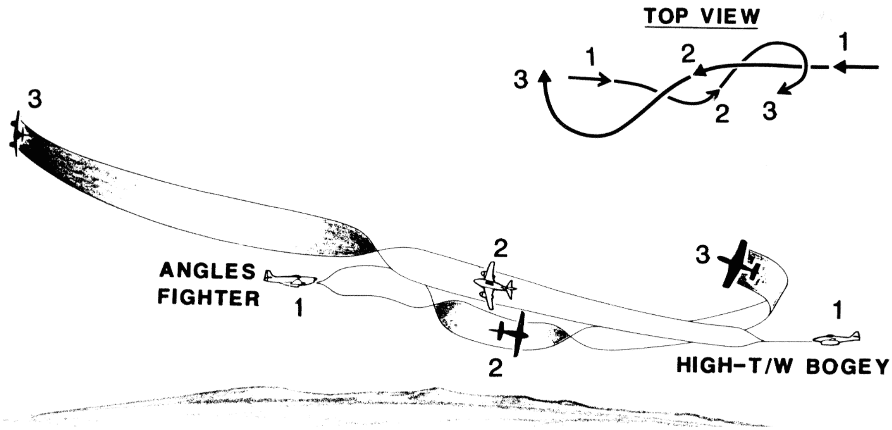

Figure 4-2. First Pass: Case 2

situation is to get inside the bogey's turn, build some flight-path separation, and lead-turn the opponent at the next pass. The farther the angles fighter can get inside the bogey's flight path during the lead turn, the more separation will be attained and the more effective the early turn will be. The pilot of the angles fighter, therefore, should "bend it around" in a tight, high-G turn to aim as quickly as possible at a point estimated to be the center of the bogey's turn, as depictd in Figure 4-3. In this particular illustration, the resultant heading initially places the angles fighter nearly in pure pursuit (i.e., pointed at the bogey); but depending on the geometry, lead pursuit, or in some cases even lag pursuit, may result. A precise visual determination of the bogey's center-of-turn is almost impossible, but it can be estimated accurately enough by noting that it will lie very nearly along a line perpendicular to the bogey's fuselage axis and at some distance from the bogey itself. Pulling a few degrees of lead on a

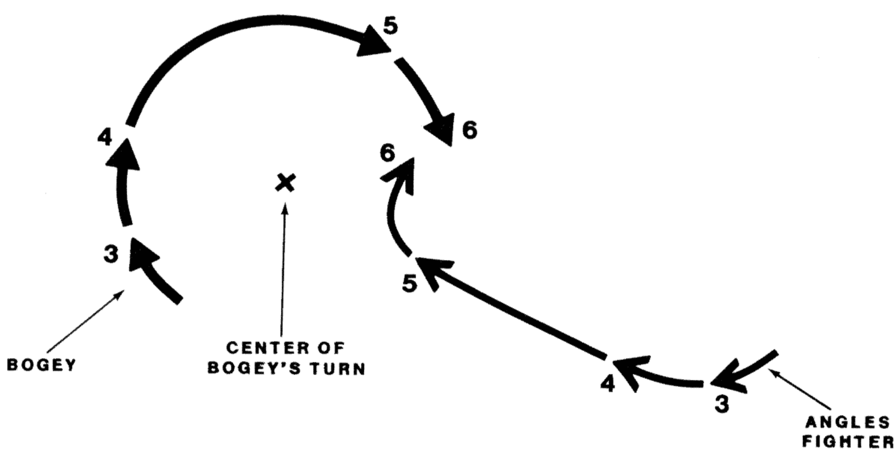

Figure 4-3. Dissimilar-Aircraft Angles Fight: Mid-Game

hard-turning bogey showing its full planform (i.e., 90° aspect) is about optimum.

Once he is established on the proper heading, the pilot of the angles fighter should try to reach his goal (i.e., the early-turn point) as quickly as possible. This generally is accomplished by an unloaded acceleration to retain any speed lost in the first turn. Airspeed should not be increased indiscriminately, however. Once his aircraft reaches the lead-turn point, the pilot should use a minimum-radius turn in order to take full advantage of the available separation. Minimum turn radius, averaged over a short period of time, usually is attained by commencing the turn at about corner speed, pulling maximum available G, and allowing speed to decay as the turn is completed. The pilot of the angles fighter, therefore, should attempt to accelerate between times "4" and "5" until his aircraft reaches corner speed. If the early-turn point has not been reached by this time, a constant-speed climb can be commenced to build additional separation in the vertical and to provide a gravity assist for the subsequent lead turn.

Determination of the early-turn point, time "5," is, as always, a matter of judgment and experience in assessing relative motion. Ideally the lead turn is conducted at near maximum G and results in passing almost directly over, under, or slightly behind the bogey for greatest advantage. This geometry is also ideally suited for a gun snapshot at the pass. Once again, however, care should be taken not to allow speed to bleed too far below that required for vertical maneuvering, just in case the bogey zooms at the overshoot. Nose-to-tail geometry makes judging the bogey's energy level even more difficult.

Figure 4-3 depicts only a very small angular advantage for the angles fighter at the pass (time "6"), and this is often the case in practice. In fact, the geometry and relative turn performance may be such that the bogey is able to achieve another neutral head-on pass. In most cases, however, doing this will require it to expend a great amount of energy, which will eventually lead to trouble for the high-wing-loaded bogey.

Time "6" in Figure 4-3 is essentially the same as time "3" in Figure 3-1 and time "2" in Figure 4-2 (except that both fighters are probably slower), so the angles fighter pilot can repeat the same reversal in an attempt to establish the more advantageous nose-to-nose condition. Depending on the advantage gained at the pass, however, it may be preferable for him just to continue nose-to-tail. Generally speaking, once the angles fighter has gained about 60° to 70° angular advantage, it is probably better for it to continue nose-to-tail. Doing so results in a considerable blind period for the bogey pilot, during which he may lose sight altogether or get nervous and pull harder, further bleeding his aircraft's energy. A reversal under these conditions causes a blind period for the pilot of the angles fighter instead, and because of the time wasted during the reversal, results in little increase in position advantage. As with nose-to-nose tactics, continued nose-to-tail turns may eventually yield a lethal position for the low-wing-loaded fighter, but arriving at this point will almost surely take longer. Once again, the angles fighter should take only what his turn-performance advantage will allow, chipping away a few degrees at a time while maintaining at least vertical-maneuvering speed.

So far in this discussion it has been assumed that the pilot of the high-T/W bogey will maneuver in the near-horizontal. He does, however, have the steeply vertical option. Figure 4-4 shows how the angles fighter pilot can cope with this situation. This illustration begins, as before, with the head-on approach. The angles fighter pilot attempts to gain flight-path separation for a lead turn, as in the previous examples; but this time, rather than taking out this separation with a close head-on pass, the high-T/W bogey immediately pulls up in the vertical. Because of the co-energy assumption of this section, the angles fighter could zoom with the bogey at this point. Even with a co-energy start, however, the greater Ps of the high-T/W bogey during the zoom would ordinarily allow it to reach a higher altitude. In cases where the Ps disparity is not too great, the angles fighter may be able to zoom high enough to threaten a gun shot at the top, forcing the bogey back down for a lead turn. In practice, however, there is usually no assurance of being co-energy at the initial pass. If instead the bogey should have a considerable energy advantage at this point, attempting to zoom with it could be disastrous. If unable to threaten the bogey on top, the pilot of the angles fighter may find himself too slow to defend against the bogey diving from above. Later in the engagement, after the angles fighter pilot has had time to ensure energy parity, zooming with the bogey can be attempted more safely. In that case a maneuver sequence similar to that described by Figures 3-2 and 3-3 might force the bogey back down for a lead turn. If he is too low on energy to threaten a gun shot on top, the pilot of the angles fighter can resort to the tactic illustrated by Figure 3-7 (i.e., hiding beneath the bogey to force it down).

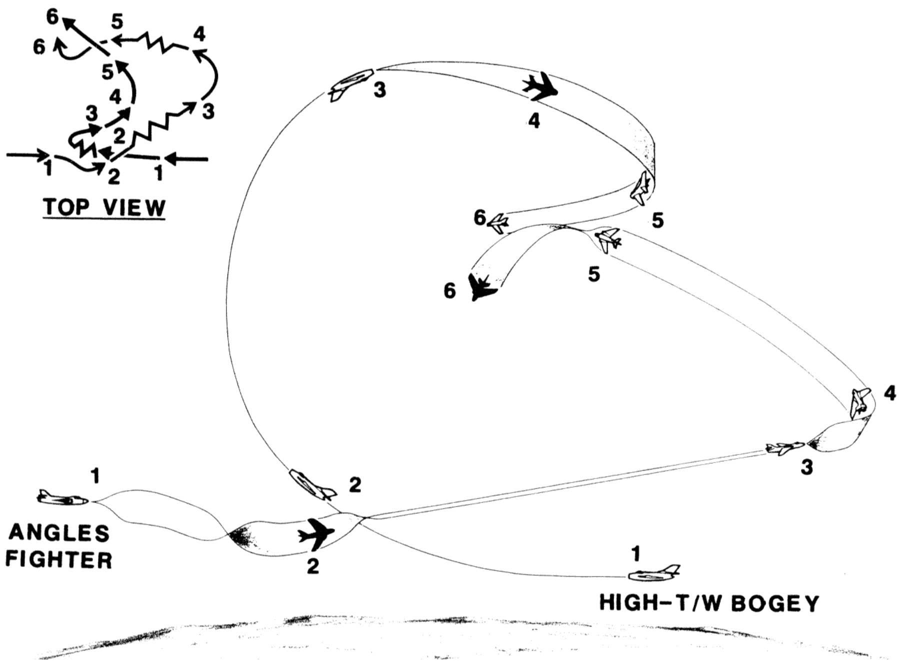

Figure 4-4. Angles Fight: Case 3

Whenever he is engaging in a zooming contest, the angles fighter pilot must take care not to allow his speed to bleed below that required for control in level flight (i.e., power-on stall speed). Once the nose is parked near vertical, it is all too easy to let the airspeed fall below this value, even to zero, in an attempt to get a few more feet of altitude out of the zoom. If this is allowed to happen, the nose of the airplane will soon become an "earth seeker," falling to a near-vertical nose-down attitude. Even if the pilot can maintain control during this maneuver, he will have very little G available with which to fend off an attack by the higher bogey, which now has been placed astutely in the rear quarter.

If it becomes apparent during a zoom that the bogey will top out much higher, the angles fighter pilot should immediately pull the nose back down to near a level attitude in a direction as far from the bogey as possible while he maintains sight of his opponent. This tactic generates separation and provides time for the angles fighter to build up some speed for defensive maneuvering.

The tactic illustrated in Figure 4-4 is more conservative and probably more appropriate early in the engagement than zooming with the bogey on the first pass. Here, on observing the bogey's zoom, the angles fighter pilot simply levels his wings and climbs. An unloaded acceleration might also be appropriate during this segment if his speed is substantially below that required for best climb performance. The climb allows the low-wing-loaded fighter to build energy at near maximum rate, while the high-T/W bogey remains at high G in its vertical pull-up, gaining little or no energy in the process. Simultaneously, the angles fighter is creating horizontal separation and reducing the bogey's altitude advantage.

The angles fighter should continue in a straight line until the bogey approaches the top of its loop. Any horizontal turning during this period merely wastes valuable energy, since the bogey can nullify any such turn simply by rolling while in a near-vertical attitude.

As the bogey approaches the top of the loop (time "3"), the pilot of the angles fighter rolls to place the bogey perpendicular to the wings (i.e., points the lift vector at it), and bends his aircraft around to generate about a 90° AOT (time "4"). At that time he can relax the G but continue to turn obliquely up toward the bogey just hard enough to hold it about 90° off the tail.

This tactic has several positive benefits for the angles fighter. The co-planar turn holding the bogey at 90° AOT presents the bogey with the highest possible horizontal LOS rate, forcing it to turn mainly in the horizontal to gain a position advantage. The bogey's shallow oblique turn at slow airspeed prevents it from gaining any great amount of energy. The angles fighter meanwhile is turning at fairly low G near optimum maneuvering speed and usually can maintain or even add energy during this segment. In addition, by allowing the bogey to remain very near the angular limits of a gun envelope, the angles fighter pilot is encouraging the opponent to continue his maneuver with hopes of success.

This "baiting" tactic is continued until the bogey approaches firing parameters of range and lead. At that point (time "5") the pilot of the angles fighter performs an out-of-plane guns-defense maneuver, nose-down in this case (essentially a high-G barrel roll underneath). Once the bogey's nose is observed to fall behind a proper lead position, the angles fighter pilot can reverse, forcing an overshoot at close range (time "6"). Such an overshoot, with the bogey co-energy or below, should provide the low-wing-loaded angles fighter with a valuable offensive position advantage. It remains only to press this advantage to a lethal position, as discussed earlier.

Now that several likely angles-fight scenarios have been presented, some attention needs to be paid to the end-game. When faced with an impending gun shot by a low-wing-loaded opponent, the pilot of a high-T/W bogey will often attempt to defend in the vertical. If he feels he can out-zoom his opponent, he is likely to try it. As discussed in the last example, when the angles fighter pilot feels he has energy parity, zooming with the bogey might be appropriate. Otherwise, the tactics illustrated by Figure 4-4 are safer.

When he is caught at slow speed with some altitude available, the pilot of a high-wing-loaded bogey is more likely to attempt a defensive spiral. As discussed in Chapter 3, this can be a very effective guns defense, and skillful use of decelerating tactics may even gain an offensive position for the bogey, particularly if the angles fighter pilot attempts to press for a gun shot as the spiral develops. If the angles fighter pilot allows the bogey some initial vertical separation, however, he can maintain an offensive position (above the bogey). The pilot of the angles fighter then simply waits and nails the bogey during its pull-out. Judging when to pull down after the bogey can be a very close call, since following too closely can result in a vertical overshoot, and excessive delay may allow the defender to dive out of range.

Should a vertical overshoot occur, however, and the angles fighter pilot find himself level with or below the bogey in the spiral, decelerating tactics should not be attempted. Instead, the low-wing-loaded fighter pilot can continue the spiral to defeat any guns solution while slowly pulling out of the dive at full power and maximum lift. The turn-performance advantage of the low-wing-loaded fighter should allow the pilot to shallow his dive angle more quickly, causing the high-wing-loaded bogey to overshoot vertically, again becoming defensive.

The Energy Fight: Guns Only

> Everything in the air that is beneath me, especially if it is a one-seater ... is lost, for it cannot shoot to the rear.
>
> Baron Manfred von Richthofen

The preceding scenarios of angles tactics should make the task of the energy fighter pilot evident. The pilot of the high-T/W fighter must avoid getting shot until he can build a large energy margin, allowing him to zoom well above his opponent and position for a high-to-low gun attack. A steep approach to a high-side gun pass helps the high-wing-loaded fighter compensate for his turn-performance deficiency. Roll rate can be substituted for turn rate to accomplish much of the heading change required in maneuvering to a gun-Bring envelope, and in a steep diving attitude the energy fighter has to oppose less gravity than it would when performing a level turn. It should be noted, however, that while the guns approach may be a steep dive, the firing pass itself usually is more successful if it can be shallowed somewhat, as discussed later. Even with these advantages, however, the pilot of the energy fighter should not expect a lengthy tracking gun shot against a well-flown low-wing-loaded fighter with a substantial instantaneous-turn advantage, since this bogey nearly always can generate enough turn performance to keep the energy fighter out of steady tracking parameters. The major exceptions to this rule occur when the bogey pilot loses sight of his attacker or the bogey is near stall speed at tree-top altitudes. Although the energy fighter pilot can work at creating these conditions, a lethal snapshot opportunity often will be achieved first.

Obvious1y, an energy fighter must have a substantial altitude advantage over its opponent immediately preceding an effective high-side or overhead gun pass. The exact amount of this required advantage depends on many factors, but in general the altitude advantage should be about equivalent to the minimum instantaneous turn radius of the energy fighter. That is, a fighter that can generate a minimum horizontal turn radius of 2,000 ft at engagement altitude and optimum speed (i.e., below corner speed) would require about a 2,000-ft altitude advantage for an effective overhead or steep high-side gun attack. A well-flown angles fighter can be expected to deny such an altitude advantage, if possible, whenever the energy fighter is near guns range. The bogey pilot may do this by zooming with the energy fighter or by saving enough airspeed to allow a vertical pull-up, if necessary, to meet the diving attacker nearly head-on.

The pilot of the high-T/W fighter, therefore, needs to build an energy advantage sufficient to allow him to zoom higher than the low-wing-loaded bogey by the required amount. Then if the bogey pilot engages in a zooming contest, the energy fighter pilot simply waits for his opponent to top out in the climb, and then pounces on him from above before the bogey can dive and gain sufficient airspeed for effective defensive maneuvering. This sequence was discussed in conjunction with Figure 2-15.

There are at least two pitfalls in this tactic, however. The most serious of these is the possibility that the zooming contest will occur before the high-T/W fighter has a great enough energy advantage. The results of this error were described under guns-only angles tactics in this and the preceding chapter and are depicted in Figures 3-3 and 3-8. The other possibility is that the bogey pilot will refuse to join in a zooming contest, but rather will use his free time during the energy fighter's pull-up to build energy for a later defensive move or a "baiting" tactic like the one shown in Figure 4-4. These are just two of the factors that make this energy fight a very difficult one.

Engaging with an Initial Energy Advantage. Depending on relative performance, the energy fighter pilot may be able to assure the desired energy advantage at the first pass by attaining a speed that is well above the maximum capability of the low-T/W bogey. This is common when a supersonic fighter engages a bogey that is limited to subsonic speeds. Just how much excess speed is required can be estimated using an altitude-Mach (H-M) diagram or Equation 3 in the Appendix before the engagement. Assuming an engagement altitude, the bogey's maximum attainable energy level can be located on the chart. Adding the desired energy (altitude) advantage to the bogey's energy level determines the approximate energy level required of the high-T/W fighter. The speed at which this desired energy level intersects the engagement altitude represents the necessary airspeed of the energy fighter.

The speed advantage necessary to provide a given zoom-altitude advantage is highly dependent on the bogey's airspeed. For example, a 2,000-ft zoom advantage over a bogey traveling at 100 knots true airspeed (KTAS) would require the energy fighter to have about 130 knots of excess airspeed (230 KTAS total). But with the bogey at 500 KTAS, the energy fighter would need about 540 KTAS (only a 40-knot advantage). Although faster bogeys require less speed advantage for the energy fighter to attain a given zoom-altitude margin, this phenomenon is offset to a large degree because faster fighters generally need more altitude margin. The figures given here are only gross estimates, since they do not consider possible energy changes during the zoom maneuver.

Assuming this energy advantage can be attained at the first pass, the pilot of the high-T/W fighter may choose to zoom immediately, as shown in Figure 4-5. The major difference between this scenario and that of Figure 4-4 comes from the great energy advantage of the high-T/W fighter in this case, which enables the energy fighter to remain well above its opponent, and facilitates its maneuvering in the vertical plane.

In this scenario the energy fighter has a substantial speed advantage approaching the pass (time "1") as well as slightly greater altitude. Together this speed and altitude advantage form the high-T/W fighter's desired energy margin. The purpose of the height advantage in this case is not only to provide extra energy margin, but also to induce the bogey pilot into a sharply nose-high maneuver. Allowing some vertical separation (i.e., passing almost directly over the bogey) gives the bogey room for a lead turn, but the pilot must turn almost purely in the vertical to take advantage of it. Too much separation here may provide the low-wing-loaded opponent a reasonable snapshot at the pass, while too little vertical advantage offers him little incentive to zoom. An altitude advantage at the pass equal to about one-quarter of the bogey's best turn radius is usually a good compromise.

In Figure 4-5 the angles fighter begins a near-vertical lead turn at time "1," while the energy fighter continues straight ahead for a few seconds. Here the pilot of the energy fighter must assess whether the bogey pilot has timed his pull-up properly to gain lead for a gun snapshot at the pass. If so, a quick out-of-plane (level) jink is in order to spoil the shot before he starts a pull-up of his own. This slight delay in the energy fighter's zoom also helps the pilot keep sight of the bogey underneath. The energy fighter should begin its pull-up, at sustained-G levels, as the bogey begins to approach effective guns range. Turning up and away from the bogey at this point increases the LOS rate seen by the bogey pilot, and consequently increases his lead requirement, forcing him to pull harder and reach a higher climbing attitude. If the bogey pilot keeps pulling for a shot, he should be committd to a very steep climb by the pass (time "2"). Mild jinks left and right during the pull-up complicate the aiming problem of the bogey pilot and may also facilitate keeping sight of the bogey.

During the next segment of this maneuver the energy fighter pilot should continue a wings-level, sustained-G pull-up, and reacquire the

Figure 4-5. Energy Fight with Initial Energy Advantage

bogey visually. Once he reaches a vertical attitude, the pilot of the high-T/W fighter can roll slightly one way or the other if necessary to align his aircraft's wings perpendicular to the bogey's position, then pull slightly past the vertical toward the bogey. During the remainder of the zoom toward time "3," the energy fighter pilot should ease to a zero-G or slightly negative-G condition in order to achieve the highest possible zoom altitude. Simultaneously, he should begin to drift toward a position almost directly above the bogey. Care should be taken, however, not to position directly above and in front of the opponent too early. If altitude separation at time "3" does not exceed the bogey's effective guns range the opponent may squirt out some lead at this point, force a defensive maneuver, and seize the offensive. When its maneuver is timed properly, the energy fighter will drift over the bogey near the top of the zoom, with maximum vertical separation, just as the bogey pilot is becoming more concerned with controlling his aircraft at slow airspeed and less concerned with aiming his guns.

After establishing the proper zoom attitude and beginning the drift toward the bogey, the energy fighter pilot may choose to roll his aircraft in the unloaded condition to point either wingtip at the bogey. This tactic, known as "profiling," reduces the presented area of the energy fighter as viewed by the bogey pilot, making it more likely that the enemy will lose sight. It also may facilitate the task of the energy fighter pilot in watching the bogey, and reduce the possibility of his flying out in front of the opponent's guns.

At time "3" the bogey runs out of airspeed and its nose begins to fall toward the horizon. Allowing the bogey to begin its pull-up first also ensures that it will top out first. Once he reaches a slightly nose-down attitude, the bogey pilot rolls upright to regain sight of the energy fighter above, and begins a nose-low, unloaded acceleration. On seeing the bogey's nose start to fall through, the pilot of the energy fighter needs to assess whether sufficient vertical separation exists for a successful gun attack. If not, the zoom can be continued until the required separation is available. Once this separation has been created, the energy fighter pilot should get his nose pointed down at the bogey very quickly to cut his opponent's acceleration time to a minimum. This may be accomplished by configuring for greatest lift (flaps, slats, etc.) and using maximum available G to drop down into the bogey's rear hemisphere for a diving gun attack.

When flying at very slow airspeeds the energy fighter pilot may choose instead to push over the top or to employ a "rudder reversal" at the peak of his zoom. Also sometimes called a "hammerhead turn," the latter maneuver causes the aircraft to rotate about its vertical axis, pivoting sideways from a nose-high to a nose-low attitude. In most aircraft the rudder reversal is performed in an unloaded condition by applying full rudder in the direction the pilot wishes the nose to fall.

This technique apparently was first used in combat by Max Immelmann, a World War I German flyer who was one of the world's first fighter aces. (He won his fifth victory within a few days of Oswald Boelcke's, another great German air fighter and tactician.) One of Immelmann's favorite tactics was to make a high-speed diving attack on his victim, then pull up vertically, perform a rudder reversal, and dive back down for another attack, and so on, until the target was destroyed. This tactic so confounded his Allied opponents that they dubbed it the "Immelmann Turn" and were convinced it defied the laws of aerodynamics. Once it was figured out, the technique was widely copied by both sides. Today there is a precision acrobatic maneuver known as an "Immelmann," but it varies considerably from the original. The modern Immelmann begins with the first half of a loop to the inverted position, followed by a roll to the upright attitude at the top.

> The Immelmann Turn was very successful. . . . But later, when more powerful engines became available, it was a dangerous move, for the lower pilot could climb after the Fokkcr and attack when it hung almost motionless in the vertical position, not under full control, and presenting an easy shot.
>
> Air Vice-Marshal J. E. "Johnnie" Johnson, RAF

Passing directly over the bogey and then pulling down toward its six o'clock almost ensures that the opponent will lose sight of the energy fighter temporarily. Faced with these tactics, the bogey pilot essentially has only two options. He can begin to turn almost immediately in a level or slightly oblique plane, attempting to regain sight and to hamper the attacker's impending gun shot, or he can continue an unloaded diving acceleration. In the first case his guns defense is not likely to be successful because of low G available at his slow airspeed. In the second option he almost surely will not regain sight of the attacker and will be forced to guess when to perform his guns break. If he guesses correctly the guns defense should be more effective at the resulting higher airspeed. An incorrect guess should terminate the engagement.

In the event that the energy fighter pilot misses the shot at time "4," a vertical overshoot is probable. At min-range the attacker can unload or roll away from the target aircraft (quarter roll away) and continue to dive for separation. Generally his speed advantage in the dive will carry him beyond guns range before the opponent can reverse and threaten a shot. This separation and speed advantage then can be used to exit the fight or to return for another head-on pass. If the vertical overshoot is not great and the energy fighter has attained at least vertical-maneuvering speed at the overshoot, the pilot may choose to pull immediately up into another vertical pitch-back and repeat his overhead attack. However, if the overshoot carries the attacker substantially below the bogey's altitude (i.e., approaching the equivalent of one attacker turn radius), the energy fighter pilot first should climb back up near the bogey's altitude before beginning a second vertical maneuver. Otherwise the altitude advantage on the top of the second pitch-back may be less than required, resulting in an even greater overshoot on the next pass.

Some modification may be required in these tactics if the energy fighter is subject to restrictions against prolonged zero or negative G. The fuel or oil systems of many power plants may cause temporary engine stoppage or even permanent damage when engines are subjected to these operating conditions. However, the pilot of the energy fighter still may be able to make use of this tactic under these conditions by relaxing the G after the initial pull-up to a slightly positive load factor for the duration of the vertical zoom maneuver.

A well-flown bogey can counter these tactics effectively in several ways. One method is not to zoom with the energy fighter at the first pass, but instead to counter with the maneuver described by Figure 4-4. Even after he is committed to a zoom the bogey pilot can complicate matters if he recognizes his situation soon enough. In this case he can break off the zoom early, before he runs out of airspeed, by leveling-off on a heading away from the energy fighter, regaining maneuvering speed, and then coming back again, as in Figure 4-4, or attempting an escape. Normally in this situation it is not advantageous for the energy fighter pilot to continue his zoom to low airspeeds in order to maximize zoom altitude. Instead he should roll as necessary to place the bogey on the lift line and continue to pull over the top of the loop at sustained-G levels. This situation is depicted in Figure 4-6.

In this example both fighters begin a zoom at the pass, as in Figure 4-5. This time, however, the pilot of the low-T/W fighter recognizes his opponent's great energy advantage and terminates the zoom, leveling off to establish a sustainable climb angle at time "3." Once he reaches a vertical zoom attitude at time "3," the energy fighter pilot sees that his opponent is leveling off, and so he continues to pull over the top of the loop at

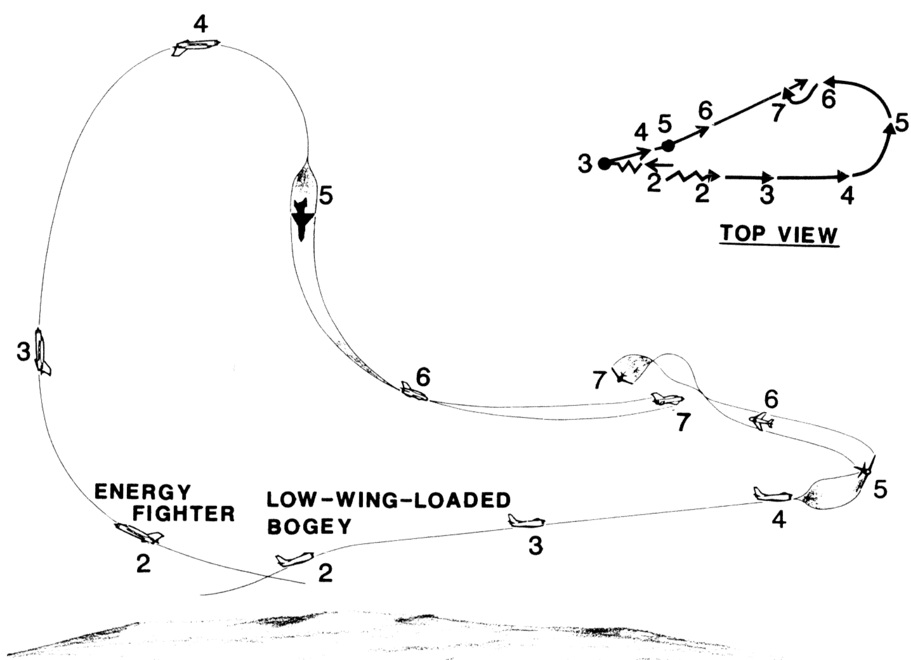

Figure 4-6. Energy Counter When Bogey Refuses to Zoom

sustained-G levels. As the energy tighter comes over the top at time "4," the bogey pilot begins a slightly climbing left turn to reengage. The energy fighter pilot continues to pull his nose down near pure vertical (time "5"), then rolls completely around to reacquire the bogey visually and to point the lift vector ahead of the bogey's current position (i.e., performs a lead roll). Once pointed downward, the energy fighter is unloaded and accelerating while performing the lead roll. The pilot continues this acceleration until approaching vertical-maneuvering speed, adjusting roll angle as necessary so that a wings-level pull-out will result in a close pass with the bogey at the next meeting. At time "6" the energy fighter pilot has begun his sustained-G wings-level pull-out. This pull-out should not be delayed any longer than necessary to achieve vertical-maneuvering speed at the bottom, since any delay can give the bogey vertical separation for a lead turn at the pass. The energy fighter pilot should resist any temptation to perform a rolling pull-out, as this wastes energy.

Approaching the pass at time "6," the bogey pilot decides to pull sharply up for vertical separation and a barrel-roll attack. If the energy fighter's pull-out has been executed properly the bogey pilot will have to do a lot of hard, energy-bleeding maneuvering to gain any substantial position advantage at the pass. In such a case the bogey is unlikely to have any vertical potential remaining. The opponent is merely attempting to intimidate the energy fighter pilot, hoping to bluff him into some energy-bleeding defensive maneuvering.

In response, the pilot of the energy fighter should be aware that his best defense is an altitude sanctuary. Defensive maneuvering should be limited to perhaps one quick out-of-plane jink, appropriately timed, followed by another pull-up (time "7"). Depending on the dynamics of the situation, this second pull-up may not have to be continued to the pure vertical. Once the energy fighter pilot determines that sufficient altitude separation will be generated by the climb and (possibly) the bogey's dive, he should terminate the pull-up immediately with a quick roll and a pull-down for a gun attack.

In the case of Figure 4-6, the energy fighter pilot was unable to avoid pulling out below his opponent at the second pass if vertical-maneuvering speed was to be reached. When possible, however, it is more advantageous to remain above the bogey's altitude throughout, so that the opponent is forced to make his attack nose-high, fighting gravity and losing more airspeed. Bottoming-out below the bogey allows it to attain a greater angular advantage at the pass and makes the enemy's bluff more believable. Except for very gross altitude overshoots by the energy fighter, however, the bogey's attack still can be adequately defeated by a quick out-of-plane jink.

> Defense against [Japanese] fighters is resolved around the superior speed of our fighters. . . . Offensive measures go according to the number of the enemy, but they are always hit-and-run because the [Zeros] can outmaneuver us about two to one.
>
> Major Richard I. "Dick" Bong, USAAF
> Leading U.S. Ace, WW-II
> 40 Victories

Engaging without an Initial Energy Advantage. All the foregoing tactics are predicated on the high-T/W fighter having a significant energy advantage at the first pass. If this cannot be assured, other methods will be required to gain this energy margin during the engagement. In order to accomplish this, it is necessary that energy performance (P_S) be optimized relative to that of the opponent. Higher T/W normally confers a P_S advantage to the energy fighter during low-G conditions, especially during unloaded accelerations and climbs. This is not necessarily so for hard-turning conditions, when the assumed larger wing or greater efficiency of the angles fighter may actually provide this aircraft with better energy performance (i.e., higher Ps for a given load factor, turn rate, or radius). Therefore, in order to optimize relative energy performance, the pilot of the high-T/W fighter needs to minimize turning and maximize low-G accelerations and climbs. Any necessary turning should be done as efficiently as possible from an energy standpoint, which usually means vertical maneuvering. Figure 4-7 illustrates how these generalities can be put into practice.

In this example the opponents approach head-on at time "1." As in previous engagements, the pilot of the low-wing-loaded bogey can be expected to attempt to generate some flight-path separation for a lead turn before the pass. The energy fighter pilot counters by turning toward the bogey to reduce lateral separation and in this way reduce the bogey's potential angular advantage at the pass (time "2").

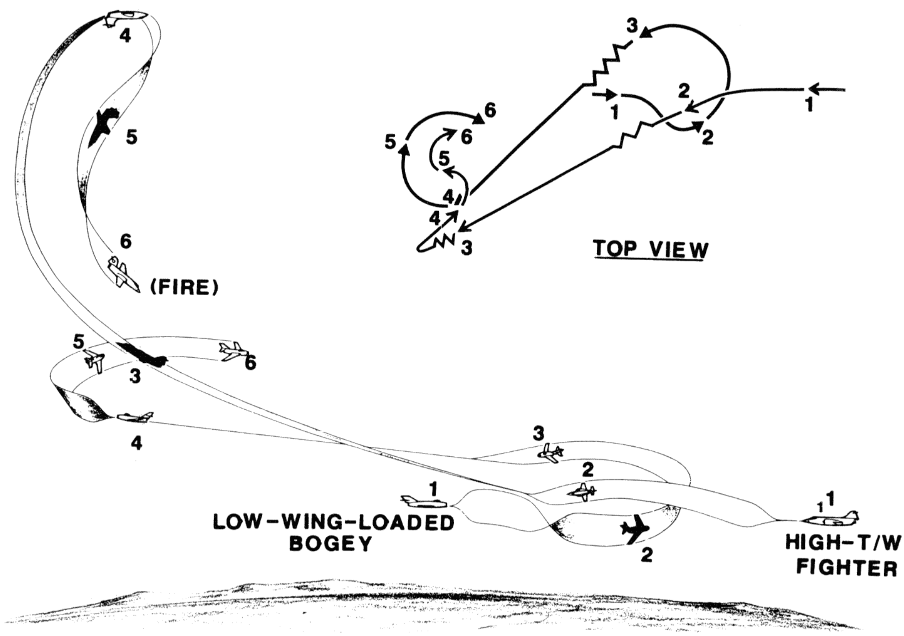

Figure 4-7. Extension/Pitch-Back Tactics

> Any angles you give the bogey on the first pass will haunt you for the rest of the fight.
>
> Lieutenant Jim "Huck" Harris, USN

Unlike in the previous example, the fighters here are assumed to have approximately equal energy (co-speed and co-altitude) at the first pass. Because of his aircraft's greater T/W the energy fighter pilot could pull up immediately and out-zoom his adversary, but this generally is not advisable. One reason for this is that the bogey may be faster than assumed. Another is the timing involved in a zooming contest. The first fighter to begin a zoom normally will peak first. Even if the low-T/W fighter cannot quite reach the same altitude, it will be considerably more maneuverable in approaching the top of its climb than the first-zooming energy fighter, which may have already peaked. At this time the energy fighter will be very slow and vulnerable as it begins to accelerate or starts back down. If the angles fighter can get close enough to threaten an attack at this point, the high-wing-loaded fighter could be in serious trouble.

To avoid this situation the energy fighter pilot accelerates to best climb speed (or, if he is faster than that, he slows by climbing steeply) and climbs straight ahead at full power. Turning during this segment should be limited to the minimum required to keep sight of the bogey. In this way the energy fighter gains separation from the bogey to preclude being menaced at the top of a subsequent zoom and also builds an energy advantage while the bogey is turning and most likely bleeding energy.

Once the bogey completes its turn and is pointed back in the general direction of its opponent (time "3"), the energy fighter pilot begins a wings-level, sustained-G pull-up to gain further vertical separation. Before its pilot commences this pull-up, the energy fighter must have at least vertical-maneuvering speed. If this value is faster than best climb speed, the climb between times "2" and "3" may have to be eliminated or cut short to allow for acceleration to the required pull-up speed. As airspeed decays in the zoom, the energy fighter pilot should constantly be reducing G to approximate the sustained-G capability of his aircraft at that speed, otherwise valuable energy will be lost in the vertical maneuver. Approaching the top of the climb (time "4") the energy fighter should be slightly faster than 1-G stall speed and be pulling only about 1 positive G while inverted.

The separation between the fighters at time "3" and the vertical maneuver of the energy fighter give the bogey pilot some breathing room between times "3" and "4." He can be expected to use this period to regain some of his energy deficit by accelerating or climbing. But since it has lower T/W, the angles fighter cannot offset all the energy margin gained by the high-T/W fighter during the earlier climbing extension. Assuming the energy fighter does not bleed energy in the zoom, it should arrive at time "4" with a significant energy advantage.

Approaching the purely vertical attitude in his pull-up between times "3" and "4," the energy fighter pilot needs to study the bogey's position and maneuver. The object is to arrive at the peak of the zoom, time "4," as near directly overhead the bogey as possible. If the bogey is still some distance away horizontally as the energy fighter reaches the vertical, it may be desirable to delay the completion of the pitch-back for a few seconds to allow the bogey to drive closer. This may be done by unloading in a near-vertical attitude and continuing the zoom. This tactic may be accompanied by profiling, as explained earlier. In this way extra altitude and time may be gained by zooming to a very slow airspeed, and then performing a rudder reversal or a pull-down at the appropriate moment.

In the case depicted, however, the bogey is near enough that the pitch-back can be continued. Therefore the pilot of the energy fighter rolls to place the bogey perpendicular to the wings, and continues to pull in an attempt to pass directly over the bogey without any horizontal maneuvering. The bogey pilot may defeat this effort by turning horizontally after the energy fighter's rolling maneuver, but this should have little effect other than further reducing the bogey's energy.

In the engagement depicted in Figure 4-7 the bogey begins a climbing oblique turn to the right at time "4." After crossing above the bogey, the energy fighter pulls steeply down toward its opponent's rear hemisphere. During the first part of this descent (between times "4" and "5") the energy fighter pilot uses lag pursuit, keeping his aircraft's nose pointed slightly behind the bogey, driving toward its extended six o'clock region. This technique results in a spiraling flight path, with most of the required heading changes accomplished by rolling the aircraft. During this period load factor should be minimized to permit greater acceleration.

This lag-pursuit technique should force the bogey pilot to turn hard and climb more steeply in order to keep sight of the diving energy fighter, thereby bleeding even more energy. At time "5" the energy fighter pilot determines that separation and angular advantage are such that an effective high-side gun attack can be initiated. Therefore he begins to turn harder, shallowing the dive angle, and pulling inside the bogey's turn by making the transition to pure, and then lead, pursuit. At time "6" the energy fighter has achieved a fairly high AOT, but it is in an effective firing position against the relatively slow and less maneuverable bogey.

In this example the high-T/W fighter's energy-performance advantage was sufficient to provide an attack opportunity after only one vertical move, but this may not always be the case. Coming over the top of the pitch-back (time "4"), the energy fighter pilot may discover that the bogey has turned early and is already near position "5," offset from directly below and much higher than before. In this situation an attack still may be possible by pulling directly into lead pursuit, turning nose-to-nose with the bogey when the maneuver is viewed from above, and reversing for the shot as firing range is approached. Usually, however, this technique results in a very steep diving approach and a high-AOT firing position that may not be effective. The steep approach also results in a large vertical overshoot after the firing pass, which could cause problems later on. Therefore, this nose-to-nose tactic is most appropriate when the energy fighter pilot intends only to take whatever shot is available at the first opportunity and then exit the fight in a high-speed diving extension.

If instead the pilot of the energy fighter intends to continue to work for an effective firing position, he still should employ lag pursuit, forcing the bogey to turn horizontally while the energy fighter is accelerating to vertical-maneuvering speed for another wings-level pitch-back. Figure 4-8 shows this tactic. In this example the energy fighter pilot comes over the top of the pitch-back at time "4" to find the bogey offset below, performing a climbing lead turn. Realizing that insufficient altitude advantage is available and too many angles have developed for an effective guns attack, the energy fighter pilot pulls vertically downward and rolls into lag pursuit, pointing the lift vector slightly behind the bogey. A rolling pull-out is continued until the aircraft has accelerated to vertical-maneuvering speed, and the roll is timed to place the energy fighter approximately opposite the course of the bogey at level-off. This technique forces the bogey to turn completely around again to pursue, and prevents it from gaining any appreciable energy. At time "5" the energy fighter can go immediately back up into a second extension and pitch-back, this time resulting in greater altitude advantage and better attack possibilities. This process can be repeated until an effective firing position is achieved or disengagement is desired.

In the descent from times "4" to "5" in Figure 4-8, it is desirable to complete the pull-out above the bogey's altitude. This keeps the bogey turning nose-high, keeps it loaded-up, and does not permit it to turn more efficiently nose-down after a vertical overshoot. Of much greater importance, however, is the attainment of vertical-maneuvering speed before the energy fighter pilot begins his next pitch-back. Scooping-out slightly below the bogey's altitude generally does not present a problem. Large vertical separations can, however, allow the bogey pilot to perform a nose-low lead turn and reach a temporary firing position during the pull-out. If forced to pull out quickly to avoid this situation, the energy fighter pilot should perform an unloaded level or diving acceleration after the pull-out to gain vertical-maneuvering speed before he attempts another pitch-back. It may be necessary to lower one wing or turn slightly to keep sight of the bogey during this extension.

One viable alternative to the climbing-extension energy tactics just discussed is the energy technique recommended for similar aircraft in the last chapter, namely, the nose-to-nose turn series at near minimum vertical-maneuvering speed, as depicted in Figure 3-4. In the case of an overly aggressive bogey, or whenever the turn-performance advantage of the angles fighter is not overwhelming, this technique may succeed in bleeding the bogey's airspeed sufficiently to permit the energy fighter to zoom safely and begin high-side guns passes.

One advantage of this method is that it facilitates keeping sight of a smaller opponent, since separations during the engagement are greatly reduced. The major drawback is that it may not be effective in the case of a dissimilar fighter. A low-wing-loaded fighter generally sustains its turn performance at a slower speed than its opponent, resulting in a smaller turn radius. This smaller radius can result in angular gains against the opponent in nose-to-nose maneuvers without bleeding energy. In addition,

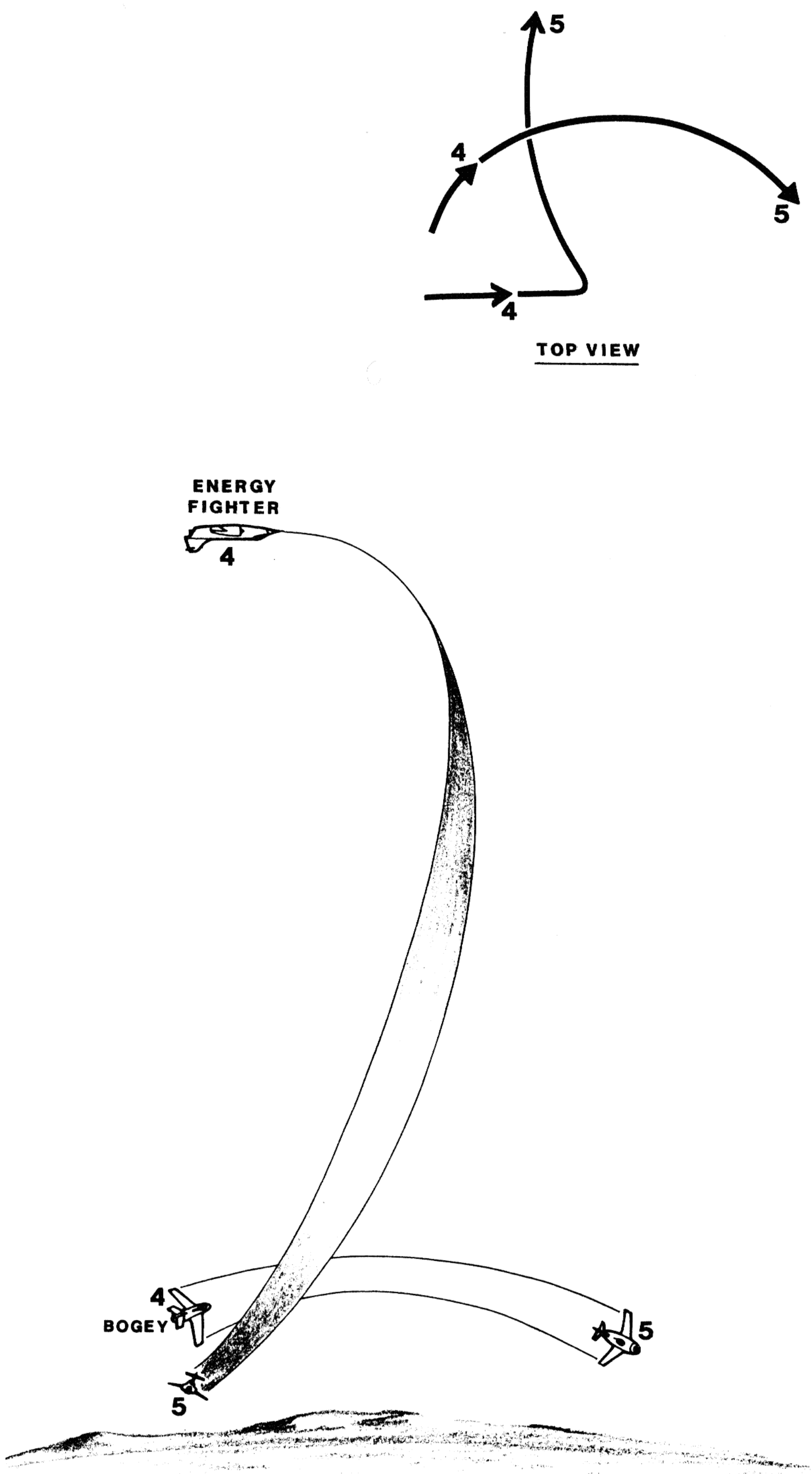

Figure 4-8. Energy Fight: Continued

the low-wing-loaded fighter's vertical-maneuvering speed is generally lower than that of its high-wing-loaded adversary, so a reduced speed can be accepted without total loss of vertical potential. Therefore, if he is patient, the angles fighter pilot can make small angular gains on each nose-to-nose turn until the energy fighter zooms with only a small speed advantage. The angles fighter pilot then may be able to zoom with his opponent and surprise him at the top of the maneuver.

The energy fighter's defense against this technique is careful observation of the bogey's maneuvering during the first few nose-to-nose turns. If after the first two turns in the series the bogey is not approaching a 90° angular advantage, the energy fighter pilot should use his superior speed to execute a nose-to-tail extension to exit the fight or to gain sufficient separation to come back, meet the bogey on neutral terms, and try something else.

Probably a better option for the energy fighter in this scenario is a sustained nose-to-tail turn. This procedure was discussed in the previous chapter; its advantages are even greater in this case. Since the low-T/W fighter seldom has a substantial sustained-turn-rate superiority, such a maneuver forces it to turn harder than sustained-G levels to gain a rapid angular advantage. The energy fighter pilot should maintain best sustained-turn-rate airspeed, or vertical-maneuvering speed, whichever is greater, in a level or climbing turn, and watch the bogey's turn performance. A shallow, climbing turn is usually preferable, since this generally induces the bogey into bleeding energy more rapidly. If it appears that the bogey will gain more than 90° advantage on the first turn, a slightly nose-low turn can be started to maintain speed while limiting the opponent's angular advantage at the pass to about 90°. In this case the energy fighter should have adequate airspeed margin at the overshoot to begin a pitch-back safely. Should the angles fighter gain substantially less than 90° after about two turns, however, the energy fighter's airspeed advantage may be inadequate. In that situation the energy fighter pilot probably should consider disengaging, since it may be better to come back the next day and hope for an easier opponent. Otherwise a nose-to-tail extension may be used to gain enough separation to come back and meet the bogey again on neutral terms. From that point extension/pitch-back tactics can be commenced.

It should be recognized that, as with economics, there is no free lunch in tactics. The tradeoffs for using the more efficient nose-to-tail turn technique, as discussed previously, include added difficulty in judging the bogey's energy and increased problems in maintaining sight. In any case, if the bogey's turn-performance advantage is very great, the energy fighter pilot may find it necessary to employ the modified spiraling pitch-back (Figure 3-10) to avoid being shot during the pull-up.

Actual combat accounts of the successful use of energy tactics are rather rare, but the following example is a beauty. Here John Godfrey's P-51B Mustang has probably 20 percent lower wing loading than the German Focke-Wulf 190D-9 opponent, and Godfrey increases his turn advantage further by skillful use of flaps. The Focke-Wulf, however, may have 20 percent better power loading. Here are two masters at work:

> A plane was approaching, and because of its long nose I thought it was a Mustang. Turning into it I received a shock; it was neither a Mustang nor an ME-109, but a new Focke-Wulf; its long nose was the latest improvement of the famed FW. These planes with the longer noses were rumored to have more horsepower than their predecessors, and were capable of giving a Mustang a rough time. We met practically head-on and both of us banked our planes in preparation for a dogfight.
>
> Around and around we went. Sometimes the FW got in close, and other times, when I'd drop my flap to tighten my turn, I was in a position to fire; but the German, sensing my superior position, kept swinging down in his turn, gaining speed and quickly pulling up, and with the advantage in height he would then pour down on my tail. Time was in his favor, he could fight that way for an hour and still have enough fuel to land anywhere below him. I still had 400 miles of enemy territory to fly over before I could land. Something had to be done. Throwing caution to the wind I lifted a flap, dove and pulled up in a steep turn, at the same time dropping a little flap. The G was terrific, but it worked, and I had the Jerry nailed for sure. Pressing the tit I waited, but nothing happened, not a damned thing. My guns weren't firing.
>
> By taking this last gamble I had lost altitude but had been able to bring my guns to bear while flying below the FW. With his advantage of height he came down, pulled up sharp, and was smack-dab on my tail again. The 20 mm. cannons belched and I could see what looked like golf balls streaming by me. A little less deflection and those seemingly harmless golf balls would have exploded instantly upon contact with my plane. "Never turn your back on an enemy" was a byword with us, but I had no choice. Turning the plane over on its back I yanked the stick to my gut. My throttle was wide open and 1 left it there as I dove. The needle stopped at 600 miles per—that was as far as it could go on the dial. Pulling out I expected at any minute to have the wings rip off, the plane was bucking so much. The last part of my pull-up brought me up into clouds. I was thankful to have evaded the long-nosed FW, for that pilot was undoubtedly the best that I had ever met.[1]

Practical Aspects of the Energy Fight. Although the foregoing tactics are academically sound in a sterile environment, there are some practical considerations which complicate matters in actual combat. One of these is the difficulty of maintaining sight of the opponent. Extension/pitch-back tactics result in great distances being generated between fighter and bogey. Additionally, the pilot of the energy fighter spends much of his time looking over his shoulder at the bogey, making visual tracking even more difficult. A very small bogey may force the energy fighter pilot into reducing his extension times, thereby achieving less energy advantage during each extension. Looking over his shoulder also complicates aircraft control for the pilot of the energy fighter. For example, it is difficult to judge a wings-level attitude for commencing a pitch-back while looking backward. The aircraft's speed and altitude also may have to be judged by feel, since the pilot may not be able to afford to take his eyes off the bogey for a peek at the gauges. This can be especially hazardous during low-altitude engagements, as more than one pilot has extended himself right into the ground while looking back over his shoulder. A second crew member is very useful for these tactics, since workload can be divided between watching the bogey and monitoring aircraft performance.

Aircraft design is another factor which must be considered. Poor rearward visibility, very high vertical-maneuvering speed (i.e., well above best climb speed), poor slow-speed control qualities, or low-G power plant limitations can make these tactics impractical. Even a cloud layer can prevent offensive use of the pitch-back.

Another consideration is the possibility of other hostile fighters in the area, or even a surface-to-air missile threat. The energy fighter is exceedingly vulnerable to such threats while at slow speed near the top of a pitch-back. Also, since pilots tend to concentrate their lockout along the horizon, the pilot of an aircraft maneuvering vertically almost assures he will be seen by nearby fighters in a wide altitude band, making attack by an unseen enemy even more likely.

All these practical considerations present severe limitations to the use of energy tactics and make their employment even in sterile situations very difficult; they require much training for proficiency. The alternatives when a pilot is armed with an aircraft having inferior turn capabilities include "hit-and-run" tactics. These usually involve stalking an unsuspecting bogey, pouncing on it in one high-speed gun attack, and exiting the area. Unlike the low-T/W angles fighter, the high-speed energy fighter usually has the option of engaging and disengaging at will, especially in the guns-only environment. Another possibility is to "gang-up" on the better-turning bogey using multiple-aircraft tactics, which is the subject of later discussions.

There is a big difference if you are in actual war or if you are playing war.
Colonel Erich "Bubi" Hartmann, GAF

The Angles Fight: Rear-Quarter Missiles Only

The pilot of a low-wing-loaded fighter equipped only with RQ weapons can employ essentially the same tactics as for the guns-only scenario. As a matter of fact, it may be necessary for this fighter to pass through the gun-firing envelope in order to reach missile parameters, which demonstrates the value of a gun even for a missile fighter. Because of the envelope-rotation effect, as explained in the last chapter, and the superior speed of the high-T/W bogey, the angles fighter generally is unable to drive directly toward the RQ missile envelope of its opponent. As long as the bogey is faster, the angles fighter pilot must employ lead or pure pursuit in order to close the range, but both these options lead to increasing AOT against a defensively maneuvering target. Once the high-wing-loaded bogey has been bled down in energy to the point where the angles fighter is actually as fast or faster, then lag pursuit can be used to reach the missile envelope.

The angles tactics already described are designed to make use of the low-wing-loaded fighter's turn-performance superiority to gain an angular advantage steadily while inducing the bogey to bleed its energy with hard defensive maneuvering. If the pilot of a high-wing-loaded bogey allows this process to continue for too long, the patient angles fighter pilot should eventually reach a lethal missile-firing position unless the opponent makes skillful and timely use of the vertical or exits the fight. Because of its much greater range the missile can create serious limitations for the energy fighter in both vertical maneuvering and disengagement.

As an example, consider the scenario depicted in Figure 4-4, where the energy fighter zooms on the first pass. When his aircraft is equipped with a missile, the pilot of the angles fighter can be much less hesitant to zoom with his opponent. He can pull up behind the bogey and fire before the energy fighter ever reaches the top of its zoom. Just the threat of such a shot usually will cause the bogey pilot to pull too quickly over the top of his maneuver in order to increase AOT before the missile can be fired. Without even firing a missile the pilot of the angles fighter can bleed the bogey's energy and reduce its zoom altitude, forcing it back down for a lead turn. Even if the bogey succeeds in generating AOT in excess of nominal missile-firing parameters, a weapon that has adequate guidance information (usually the target's exhaust heat) still may be successful, since the target will be slow and unable to maneuver effectively in defense.

One probable ploy a high-T/W bogey may use involves climbing toward the sun. By placing his aircraft between the sun and the angles fighter, the bogey pilot may be able to avoid a hostile heat-seeking missile shot, since such a weapon most likely would be decoyed by the sun's heat. It can also become very difficult to keep sight of the opponent when a pilot is forced to look very near the sun. A dark-colored helmet visor is useful in these situations, especially one that can be flipped down into position at critical moments and removed quickly from view when not needed. Generally visors (even "clear" ones) are not recommended in the air-combat environment, since anything extra between the pilot's eyes and his adversary makes visual acquisition and tracking more difficult.

Another useful technique for watching a bogey close to the sun is to close one eye and block out the sun's disc with the palm of the hand, a thumb, or a fingertip. This technique usually is effective unless the bogey pilot positions his aircraft perfectly in the sun, which is quite difficult to accomplish.

> I closed one eye, holding the tip of my little Hnger up in front of the open orb, blocking out just the fiery ball of the sun in front of my opened eye. I found that it was impossible for an enemy to come down from out of the sun on a moving target without showing up somewhere outside of my fingertip if I continuously kept the fiery part from my vision.
>
> Colonel Gregory "Pappy" Boyington, USMC

A radar also is quite helpful in these situations for fighters so equipped. As soon as the angles fighter pilot recognizes the opponent's intention to seek sun masking, a radar lock should be established. Then, if the bogey subsequently is lost in the sun, the radar may provide valuable clues as to where to look to reacquire it visually. One dirty, rotten trick to watch for in these cases is a reversal in the sun. For instance, the bogey may appear to fly into the sun from the left side, reverse directly in the sun, when it is not visible, and come out unexpectedly on the left side.

The angles fighter pilot also can maneuver to complicate the bogey's attempts at sun masking. For instance, if the bogey begins a near-vertical zoom toward the sun, the angles fighter pilot can fly left or right, perpendicular to the opponent's flight path. Likewise, if the bogey is well above and approaches the sun from one side, the angles fighter pilot can fly horizontally toward or away from the sun with the same effect, or he can perform steep climbs or dives.

The missile's range greatly complicates the energy fighter pilot's attempts to disengage. When the bogey attempts to run, the angles fighter often can turn hard, point, and shoot before the target can exceed maximum range. This is especially true when the energy fighter pilot is most likely to disengage, that is, when he begins to feel defensive with his speed reduced and his opponent at an angular advantage. Once a missile has been fired the target usually will perform a defensive break turn, further reducing its energy. Continued defensive turning against the missile, or an attempt to preclude a firing by turning to hold the attacker at high AOT, results in arcing. The angles fighter pilot then can use lead pursuit to close the range once more and force continuation of the engagement. Firing a missile "for effect," even when the target is out of range, often will induce a defensive turn and preclude the bogey's escape.

> I started shooting when I was much too far away. That was merely a trick of mine. I did not mean so much to hit him as to frighten him, and I succeeded in catching him. He began Hying curves and this enabled me to draw near.
>
> Baron Manfred von Richthofen

Once angles tactics have succeeded in placing the low-wing-loaded fighter in gun-firing parameters, it may be too close and at too great an AOT for a RQ missile shot. Figure 4-9 shows how the desired position may be attained. At time "1" in this example, the angles fighter is in pure pursuit inside the bogey's turn and in its rear hemisphere, but it is too far off the target's tail for an effective RQ missile shot. (The nominal firing envelope is shown behind the target at positions "1" and "4. "(The geometry of the situation is such that continued pure pursuit on the part of the angles fighter would allow it to close, but it would remain outside angles parameters until it was inside minimum firing range. The bogey is forced to continue its arcing defensive turn, since any relaxation in G allows the attacker to drift deeper into the rear hemisphere.

To begin the transition to RQ missile parameters, the attacker first pulls some lead (time "2") to increase closure. Once he is established in lead pursuit the attacker relaxes his turn, allowing the bogey to drift toward his nose at close range, then continues a lead turn to pass as closely as practical behind the bogey (time "3"). A maximum instantaneous turn is then performed to bring the nose to bear on the target before max-range is exceeded or the envelope rotates away (time "4"). By passing as close to the bogey as practical at time "3," the attacker makes

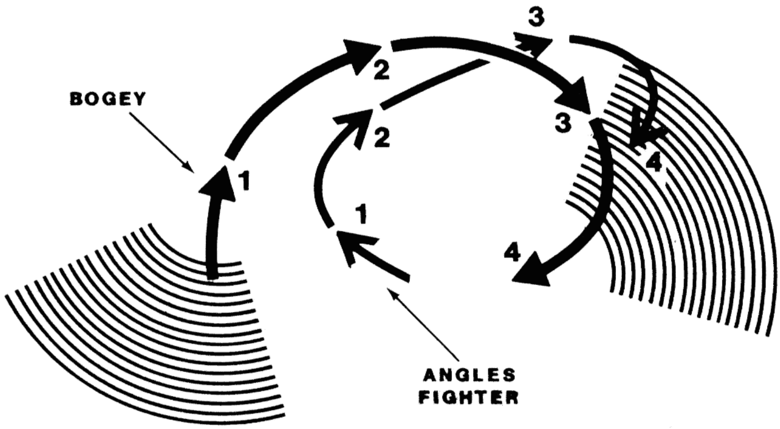

Figure 4-9. Transition to Rear-Quarter Missile Envelope

more time available for the shot before the target can open to max-range. The optimum speed for the angles fighter at time "3" is somewhat above corner speed, as this maximizes its average turn-rate capability during the turn from time "3" to time "4." Time "1" is also a good opportunity for a lag displacement roll, which may be equally effective. Note that the attacker probably passes through an effective gun snapshot envelope between times "2" and "3," and he can take advantage of it should he be so equipped.

At time "3" in this scenario, the bogey pilot may decide to reverse, probably spoiling the shot. This should only delay the inevitable, however, since the attacker can retain the offensive and repeat his transition attempt from the other side. Each time the bogey pilot performs such a hard reversal he further bleeds his energy.

Another option for the bogey at time "3" is a vertical pull-up. In this case the attacker must decide whether his performance will allow him to pull up behind the bogey and get off a shot. Obviously, vertical-maneuvering speed would be desirable at this point, but it may not be required. The angles fighter only has to get its nose high enough to point at the target and fire before running out of airspeed. This is a risky proposition, however, since if the shot is missed for some reason, the angles fighter is left in a very vulnerable position. The safer option is to extend away, as shown in Figure 4-4, and return on better terms.

The Energy Fight: Rear-Quarter Missiles Only

As difficult as the energy fight is in the guns-only environment, the substitution of RQ missiles further complicates matters, both offensively and defensively. Although the energy tactics described offer reasonable prospects of attaining a lethal gun snapshot against a low-wing-loaded adversary, this generally is not the case when the fighters are limited to RQ missile parameters. A more maneuverable fighter nearly always seems to have the turn performance necessary to rotate its lethal cone away from an opponent at just the critical moment. The exception to this is when the low-T/W bogey is very slow and is unable to create a tracking-rate problem for the missile. In such cases "RQ only" missiles can assume all-aspect capabilities. Against a well-flown bogey, however, this situation is quite difficult to generate, and even if it was possible it might take longer than combat endurance or prudence in the combat environment would allow. Against a bogey of known limited combat endurance, however, energy tactics do offer a means of remaining neutrally engaged until the bogey pilot is forced to retire for fuel considerations. At that time he becomes quite vulnerable. Running the opponent out of gas is as good as shooting him.

Because of the constraints of the weapon, the immediate goal of energy tactics in the RQ missile scenario might well be causing the opponent to lose sight. Use of extension/pitch-back tactics, as shown in Figure 4-7, can be quite effective for this purpose, especially against a larger bogey. The extension from time "1" to time "3" in this example presents the bogey pilot with a tail-aspect view of the rapidly retreating energy fighter. This reduced presented area and extended range while the bogey is in a high-G turn (which reduces the pilot's visual acuity by lowering blood pressure to his eyes) enhances the probability that the bogey pilot will lose sight during this segment.

> You can't fight what you can't see.
>
> Unknown

Another factor of prime concern to the energy fighter pilot is sun position. Whenever practical, each extension and pitch-back should be made in the direction of the sun, forcing the opponent to look up-sun as much as possible. This is particularly important in the RQ missile scenario, since maintaining sight is more difficult for the bogey pilot in such situations, and the presence of the sun also may preclude a heat-seeking missile shot during the extension or subsequent pitch-back. Both these factors are so critical in this scenario that some preengagement consideration and maneuvering, or even a level nose-to-tail turn after the first pass, may be justified so that the extension and pitch-back can be made toward the sun.

During the pitch-back itself, profiling should be used whenever practical to make visual acquisition even more difficult. Arriving at the top of the pitch-back (time "4" in Figure 4-7), the pilot of the energy fighter should attempt to pass directly over the bogey and use lag pursuit, as depicted, to spiral down toward the firing envelope. Great attention should be paid to remaining in the bogey's hard-to-watch high six o'clock region during this approach so that the energy fighter is more difficult to reacquire if the bogey pilot has lost sight. Although reaching the RQ firing envelope may be difficult, the prospects are greatly enhanced if the bogey pilot has lost sight, since the usual tendency is for him to relax his turn noticeably under these conditions. If this process does not cause the opponent to lose sight, further extension/pitch-back attempts can be made as combat endurance permits.

If during a diving attack it becomes apparent that the bogey pilot has not lost sight, the energy fighter can continue hot-side lag pursuit, forcing the opponent to continue his hard turn and discouraging a reversal. The energy fighter should maintain a respectful distance from its opponent during this maneuver, within missile-firing limits, while building speed. An overshoot and subsequent bogey reversal during this period can place the energy fighter in a hazardous position. Once he regains vertical-maneuvering speed, the pilot of the energy fighter has the option of continuing a level turn in lag pursuit until his nose is pointed toward the sun, which is normally the optimum moment for another extension. Or the energy fighter can employ the nose-to-tail extension maneuver depicted in Figure 3-12.

Along with the techniques already discussed, there are some other practical points worth mentioning about becoming invisible and staying that way during a pitch-back. For instance, the energy fighter pilot should be aware of the contrail level. Depending on air temperature and humidity, the water vapor in the exhaust of both jet and reciprocating engines may condense to form a vapor trail that can turn a small invisible fighter into an airliner, visible for a hundred miles. This is generally a high-altitude phenomenon that can be predicted fairly accurately by meteorologists. A more accurate determination of the contrail level can be made prior to engaging by checking for a contrail during a climb. It should be recognized, however, that the contrail level also is sensitive to exhaust temperature, so this check should be made at combat power when practical. For instance, jet contrails may appear at different altitudes depending on whether or not the fighter is using afterburner. The contrail most often becomes a factor approaching the top of a pitch-back in a high-altitude fight. The contrail level may require completing the vertical maneuver as quickly as possible rather than continuing a zoom to the highest attainable altitude.

Another consideration is known as the "burner puff." Many jet engines will exhaust a considerable amount of unburned fuel whenever afterburner is selected and/or deselected. This fuel may leave a puffy "cloud" or short contrail, calling attention to the fighter's position. If this is known to be a problem, the energy fighter pilot should select afterburner early in the engagement and resist the temptation to change power settings if there is any possibility that the bogey pilot has lost sight. Such changes can be made when the energy fighter is passing close to the opponent, obviously in plain view, or when it is positioned in the bogey's blind zone.

> It's the little things that cost you victories.
>
> Croup Captain Reade Tilley, RAF

"Vortex trails" also may cause problems for the energy fighter. These are condensation trails that are formed when air pressure is suddenly reduced as the air passes over an aerodynamic surface. Particularly prevalent in humid conditions, these condensation trails m-iy stream considerable distances behind wingtips or other high-lift areas of the aircraft, especially when a vortex is present. Under given conditions of humidity, vortex trails may appear at a predictable G level. If the offending load factor is determined before the engagement, the energy fighter pilot might be able to reduce or eliminate vortex trails by holding G below this level during critical portions of vertical maneuvers. Under some conditions, however, vortex trails may be produced at such low G that they are unavoidable.

A natural phenomenon that actually can aid the energy fighter pilot in positioning his aircraft properly between the bogey and the sun is known as the "pilot's halo." This effect, which is caused by diffraction of sunlight around the body of an aircraft, often produces a ring of light which is visible against the terrain or clouds below. In hazy or humid conditions, this circle of light may appear to be suspended in the air and drift along beneath the aircraft that produces it. When the aircraft's shadow is visible, it will appear in the center of the halo. Therefore, when the bogey also appears in the halo its pilot must look directly at the sun to see his opponent. With a little practice the energy fighter pilot can learn to "fly" his halo over the bogey to complicate visual acquisition and tracking.

One further consideration in the energy fighter's attempt to disappear is electromagnetic emission. As mentioned earlier, many fighters are equipped with radar-warning receivers that serve to detect radar signals from enemy aircraft and display the direction of the threat to the pilot. Since the RQ heat-seeking missile generally is not dependent on radar input, the energy fighter might consider turning off his radar transmitter during an engagement with an RWR-equipped adversary. If practical, this procedure might conceal the attacker's position at a critical moment.

Because of the importance of the energy fighter's disappearing act in the RQ missile scenario, extension tactics may be more productive than the nose-to-nose or nose-to-tail options described, particularly when there are great performance differences between the aircraft. When the sun is very high and bright, when performance does not vary too widely between fighters, or when a large energy fighter is engaging a much smaller angles fighter, however, these tactics may be more useful. The greater turn performance of the angles fighter in this scenario almost necessitates use of the modified spiraling pitch-back by the energy fighter, as depicted in Figure 3-10. Special emphasis is required on pitch-back timing and use of the sun. Starting a pitch-back before the bogey is committed to an overshoot, allowing the opponent to gain too much angular advantage, failing to pull up into the sun, or misjudging the bogey's energy can be fatal.

If things do not appear to be going well, the energy fighter pilot should consider disengaging before becoming decidedly defensive. Disengaging from a missile fighter, however, can be more difficult than in the guns-only scenario. The energy fighter pilot should attempt to maintain high speed, and he should pass the bogey with minimum flight-path separation as close to head-on as practical. He can then perform an extension while turning in the nose-to-tail direction only enough to maintain sight of the bogey. It is very important to watch the opponent throughout the disengagement to observe any possible missile firing. The bogey should be held very near the rear visibility limits of the energy fighter to increase the opening velocity component. Maintaining approximately a 90° angle of bank during this extension may allow the energy fighter pilot to keep sight and reduce the requirement for turning. The nose of the aircraft can be allowed to fall, producing a ballistic flight path, which will increase accelcration and decrease altitude, both of which will reduce the bogey's maximum firing range. Viable alternatives include pulling up and extending away toward the sun, as well as ducking into a cloud, either of which should preclude a heat-seeking missile shot.

The retreating energy fighter pilot should not attempt to avoid a missile firing by turning to increase AOT, as this results in arcing, which may allow even a slower opponent to close the range and force reengagement. If a missile is fired at what appears to be near max-range, the target pilot should employ all available defensive countermeasures short of maneuvering (flares, chaff, power reduction, etc.) first, while watching the progress of the missile. A defensive break turn should be made only when the target pilot cannot stand to wait any longer. Even then, such a turn should be continued only as long as absolutely necessary before resuming the extension. If the break is delayed, the missile may run out of poop. The first indication of this is often oscillations of increasing magnitude in the missile's flight path.

The Angles Fight: All-Aspect Missiles Only

Essentially all the comments pertaining to the angles fight between similar fighters equipped with all-aspect missiles are relevant in this dissimilar-fighter scenario. The tactics discussed in relation to Figure 3-11 are particularly effective in this case because of the turn-performance advantage of the low-wing-loaded fighter. One complication might be the loss of energy resulting from the hard prefiring turn (between times "2" and "3" in Figure 3-11). After firing the missile, or if he does not take the shot for some reason at time "3," the pilot of the angles fighter should relax his turn and accelerate to regain some of this lost energy before the next pass. The subsequent maneuvering might resemble that depicted in Figure 3-3, and it could be followed by another nose-to-tail turn attempt.

The Energy Fight: All-Aspect Missiles Only

This is a very unenviable scenario for a high-wing-loaded fighter. The extension/pitch-back technique may be workable against a heat-seeking missile, provided the pitch-back is made into a high sun. The shot provided the energy fighter pilot by this tactic generally will be forward-quarter, looking almost straight down on his target, as he comes over the top of his vertical maneuver. Without proper sun protection, the energy fighter will be vulnerable to the bogey's missile during the pitch-back, as the low-wing-loaded fighter will reach a firing envelope first. Against a radar-missile-equipped opponent, this tactic is probably suicidal. Essentially the same comments apply to engaging with an initial energy advantage, as depicted in Figure 4-5, except that this method may be safer than extension/pitch-back tactics when the sun is extremely high.

Level nose-to-tail turns should be avoided, since these result in precisely the situation shown to be optimum for the angles fighter in this scenario. The nose-to-nose series introduced in the last chapter (Figure 3-4) and amplified in the discussion of energy tactics earlier in this chapter may be viable here. Nose-to-nose geometry keeps aircraft separation to a minimum and may "trap" the angles fighter inside its min-range firing requirements. If the bogey's energy can be bled sufficiently in this manner to deny it any vertical potential, a spiraling pitch-back (Figure 3-10) may result in a shot opportunity for the energy fighter. This may be the only viable tactic against a dogfight-capable radar missile, but it is still exceedingly dangerous. A competent pilot in a low-wing-loaded fighter usually can preserve enough vertical potential to get his nose up for the shot before the energy fighter can complete its pitch-back.

Coming over the top of the vertical pitch-back, the pilot of the energy fighter should attempt to fire at his first opportunity and then assume lag pursuit. Continuing in pure pursuit while diving, such as when the attacker is pressing for a better shot as min-range is approached, may result in an overshoot, with dire consequences. If the bogey is equipped with a heat-seeking all-aspect weapon, skillful use of the sun may allow multiple pitch-backs and diving attacks. Ordinarily, however, a second pitch-back after a lag-pursuit maneuver will be commenced with considerable lateral separation, possibly allowing the bogey to reach firing parameters more easily. If the energy fighter survives one pitch-back in this scenario, the pilot should probably consider himself fortunate and follow his attack with a nose-to-tail extension and disengagement as shown in Figure 3-12.

In this very difficult scenario, probably the best tactic for the high-wing-loaded fighter is to shoot first, head-on, before the first pass, and exit the fight regardless of the results of the shot. An even better alternative, when possible, is to sneak up on the enemy and shoot him in the back—unless points would be deducted for sportsmanship!

Multiple- Weapons Considers tions

As discussed in the last chapter, modern fighters often carry a combination of air-to-air weapons, generally guns together with either RQ or all-aspect missiles. This offers the pilot some choice as to which weapons envelope he should attempt to satisfy first.

In the case of the low-wing-loaded fighter, the addition of the RQ missile to his arsenal has little effect on the pilot's tactics in the sterile one-versus-one environment, except to make his task somewhat easier. He should still consider the gun to be his primary weapon, but, as explained in the RQ-missile-angles-fight section of this chapter, the missile serves to deny the high-T/W bogey the option of disengaging at will. The missile also allows the angles fighter pilot to threaten his high-T/W opponent more seriously from a position of greater energy disadvantage and offers a more potent offense against the bogey's energy tactics. The gun and the rear-quarter AAM are very complementary weapons systems for the low-wing-loaded fighter.

For the high-wing-loaded fighter, however, this is not nearly so true. As previously explained, such a fighter has little chance of achieving a RQ missile envelope against a low-wing-loaded opponent who can maintain visual contact. In general, this scenario offers the high-T/W fighter two options. The high-risk option is to employ guns tactics in an effort to achieve a snapshot. More attention must be paid to sun position and pitch-back technique, however, because of the bogey's missile threat. The greatest elements of risk in this option involve the possibility of a missed gun shot and the almost inevitable low-TCA, close-range overshoot, which may allow the bogey to reverse for a missile shot. The more conservative approach is to use RQ missile tactics, firing high-angle shots down at the bogey from above, and concentrating on causing the opponent to lose sight. This approach offers better escape opportunities. A note of caution is in order here, however. Although the second option may be safer in the sterile environment, it may take more time, thereby exposing the energy fighter pilot to greater risk in a hazardous combat arena. Furthermore, the added time may not be available if combat endurance is limited.

When both aircraft are equipped with guns and all-aspect missiles, the pilot of a low-wing-loaded fighter is faced with a similar choice. Here the quick and dirty solution is the nose-to-tail turn and forward-quarter missile tactic depicted in Figure 3-11. The risk here again is that of a missed shot, possibly because of sun position, weapons-system malfunction, or missile misfire, since this tactic leaves the angles fighter open to a retaliatory shot from the bogey. The more conservative option in this case is to employ guns tactics, attempting to stay close to the bogey (by nose-to-nose turns, etc.), trapping its missile inside min-range limits. The angles fighter pilot should exercise caution, however, not to expend so much energy in attempting a gun shot that he cannot get his nose up for a missile shot if the bogey zooms. In this scenario the gun should be used more as a threat than as a primary weapon. Its function is to cause the high-T/W bogey to bleed energy and then to attempt an escape, either by zooming or diving, both of which should be fatal. The angles fighter pilot should employ guns tactics conservatively, taking any shot that is offered, but the all-aspect AAM in most cases still will be the lethal weapon. The greatest disadvantage of guns tactics is the increased time involved. In the case of a small bogey, however, this factor may be outweighed by the reduced separation distances, which facilitate maintaining visual contact.

Unfortunately for the energy fighter, the dismal prospects just described are about as good as they get in this scenario. The combination of the dogfight-capable all-aspect missile and the turn-performance superiority of the low-wing-loaded bogey is extremely dangerous. As discussed in the all-aspect-missile-energy-fight section of this chapter, nose-to-nose turns can be used to bleed the energy of an overly aggressive opponent; but the addition of the gun in this scenario makes this tactic even more hazardous and difficult. An extension and pitch-back into a high sun may be workable in the case of heat-seeking AAMs; lots of luck is required against a radar missile. One possibility, especially against a larger bogey, is a diving, nose-to-tail extension after the first head-on pass. This tactic may cause the bogey pilot to lose sight, allowing the energy fighter to come back for a shot. Even if the opponent maintains visual contact, the extension may exceed his maximum firing range until the energy fighter begins its comeback. A level or nose-low turn by the energy fighter to reengage can place the bogey in a look-down situation, possibly reducing the effectiveness of its missiles, while the energy fighter has optimum look-up. Off-boresight firing capability can be quite valuable here in the attempt to get off the first shot. It may be necessary to reduce power during the reengagement turn to delay the bogey's heat-seeking missile-firing opportunity, if it is so equipped. Full power can be reapplied after the bogey reaches min-range;

but even so, this defensive tactic will result in great loss of energy, leaving the high-wing-loaded fighter very vulnerable if the bogey is not destroyed.

Dissimilar Weapons

Just as the performance of the two opposing fighters may be dissimilar, their weapons capabilities also may vary. In addition to the similar-weapons scenarios for the aircraft-performance pair already discussed, there are at least twenty possible combinations of aircraft performance and weapons loads. Obviously, covering all these possibilities would become rather tedious and is probably unnecessary. Instead, only a couple of the more likely combinations are addressed.

Until the 1950s, guns and unguided rockets were essentially the only air-to-air weapons available. At about that time the RQ heat-seeking AAM became operational. Some existing fighters were retrofitted to carry this weapon, and other new fighters were designed for its employment. Many of the new designs stressed high T/W for supersonic speed capability at the expense of wing loading and turn performance. It was theorized that the great speeds of these new fighters would preclude the classic turning dogfight, so turn performance was no longer important. Likewise, the gun would not be an effective weapon in this environment, so it was eliminated from some new designs in favor of missiles. These trends eventually resulted in combat between older, low-wing-loaded fighters equipped only with guns, and newer high-T/W fighters having guns and missiles or only missile armament.

The addition of RQ missiles for the high-T/W fighters has little effect in the sterile one-versus-one guns-only scenario already discussed. In actual combat, however, the AAM provides several important benefits. The most likely time for satisfying RQ missile-firing parameters remains those instances when the low-wing-loaded bogey pilot does not have sight of the attacker, loses sight, or attempts to escape. Under these conditions the missile affords greater lethality than the gun and usually enables a quicker kill since it does not require running the bogey down. Firing the missile also requires less time and concentration than gun shots do. All of these factors combine to make the high-T/W fighter less predictable and less vulnerable in a hostile environment. Whether or not the high-T/W missile fighter has a gun, energy tactics are considerably safer and more workable against a guns-only bogey, as the inherent high speeds and greater aircraft separation common with these methods make the opponent's task more difficult. The missile shot may be more difficult for the energy fighter to obtain, but attempting it is less risky. A missed gun shot against a low-wing-loaded opponent can leave the energy fighter slow and very defensive. For this reason (endurance and environment permitting) it may be more prudent for the energy fighter pilot to wait for the missile shot rather than to attempt a quick guns kill.

Enemy RQ missiles cause two serious problems for the low-wing-loaded gunfighter. Since an attacker can fire at much greater range with these weapons, initial visual detection of an attack is more difficult. In addition, the missile further complicates the chances of this fighter being able to escape once it is engaged. Tactics for the gunfighter would not change appreciably, however, with angles tactics still being appropriate. Maintaining an angular advantage at close range with angles tactics effectively removes the RQ missile threat. When the high-T/W bogey is not also equipped with a gun, the pilot of the low-wing-loaded gunfighter can be even more aggressive. Lack of a short-range, all-aspect weapon leaves the bogey defenseless against radical lead turns, and makes it more difficult for the bogey pilot to capitalize on an overshoot by the gunfighter.

> A fighter without a gun ... is like an airplane without a wing.
>
> Brigadier General Robin Olds, USAF

During the early years of the Vietnam conflict the low-wing-loaded, low-T/W MiG-17 Fresco opposed the U.S. F-4 Phantom. With nearly a ten-year technology advantage, a powerful air-to-air radar, semi-active radar-guided Sparrow missiles, RQ heat-seeking Sidewinders, and supersonic speed capability, the Phantom might have been considered more than a match for the subsonic, guns-only MiG-17. Several extenuating circumstances, however, greatly altered the balance. The long-range, all-aspect Sparrow missile, for instance, often could not be used, since it was usually impossible to identify the target as hostile except visually at close range. By that time the MiG-17 was probably inside the weapon's min-range capabilities and tended to remain there during subsequent maneuvering. Since this missile was not "dogfight compatible," and the Phantoms generally lacked gun armament, only the RQ Sidewinder remained viable against the more maneuverable MiG. Even so, energy tactics should have allowed the F-4 to escape or to remain neutrally engaged until the MiG pilot lost sight or had to retire. Unfortunately for the Americans, the Phantom crews often were poorly trained in energy techniques, were faced with a much smaller enemy aircraft that was hard to track visually, and sometimes lacked the combat endurance for extended engagements far from their bases. These circumstances often led to hard-turning engagements, to the advantage of the MiGs. The MiGs also were generally blessed with better ground-based radar control and could spot and identify the Phantoms at long distances because the F-4 engines smoked badly. Therefore, the MiGs often reached a firing position, or at least gained substantial advantage, before being detected. The Vietnamese pilots, however, generally lacked the proficiency necessary to take full advantage of their many opportunities, and they lost somewhat more fighters than they downed in air combat.

Late in the war, U.S. Navy pilots reaped the benefits of improved air combat training provided by the newly formed Navy Fighter Weapons School (TOPGUN) at Miramar Naval Air Station in California. The following excerpt is found in *Fox Two* by Commander Randy "Duke" Cunningham. In this engagement Cunningham and his backseat Radar Intercept Officer, "Willie" Driscoll (sometimes called "Irish"), bagged their fifth victory (third on this mission) to become the first U.S. aces in Vietnam. They were flying a F-4J Phantom with semi-active radar Sparrow and heat-seeking Sidewinder missiles (no guns); their opponent was a battle-wise Vietnamese ace in a MiG-17 Fresco that was probably equipped only with guns (although at the time some were rumored to be carrying heat-seeking Atoll missiles). Under these combat conditions the F-4 is estimated to have a T/W advantage of about 20 percent, but a wing loading 80 percent greater than that of the MiG. Cunningham attempted to employ energy tactics in this fight and met with little success against the well-flown bogey. Frustrated, Duke finally pulled a desperate gamble and won. Incidentally, "Fox Two" is a radio call used to warn other friendly aircraft in the area of an impending Sidewinder missile launch.

> As we headed for the coast at 10,000 feet, I spotted another airplane on the nose, slightly low, heading straight for us. It was a MiG-17. I told Irish to watch how close we could pass the MiG to take out as much lateral separation as possible so he could not convert as easily to our six o'clock. We used to do the same thing against the A-4s back at Miramar since the two aircraft were virtually identical in performance. This proved to be my first near-fatal mistake. . . . A-4s don't have guns in the nose.
>
> The MiG's entire nose lit up like a Christmas tree! Pumpkin-sized BBs went sailing by our F-4.1 pulled sharply into the pure vertical to destroy the [enemy's] tracking solution. As I came out of the six-G pull-up I strained to see the MiG below as my F-4 went straight up. I was sure it would go into a horizontal turn, or just run as most had done in the past. As I looked back over my ejection seat I got the surprise of my life: there was the MiG, canopy to canopy with me, barely 300 feet away! ... I began to feel numb. My stomach grabbed at me in knots. There was no fear in this guy's eyes as we zoomed some 8,000 feet straight up.
>
> I lit the afterburners and started to outclimb my adversary, but this excess performance placed me above him. As I started to pull over the top, he began shooting. My second near-fatal mistake—I had given him a predictable flight path, and he had taken advantage of it. I was forced to roll and pull to the other side. He pulled in right behind me.
>
> Not wanting to admit this guy was beating me, I blurted to Willie, "That S.O.B. is really lucky! All right, we'll get this guy now!" I pulled down to accelerate with the MiG at my four o'clock. I watched and waited until he committed his nose down, then pulled up into him and rolled over the top, placing me at his five o'clock. Even though I was too close with too much angle-off his tail to fire a missile, the maneuver placed me in an advantageous position. I thought I had outflown him—overconfidence replaced fear.
>
> I pulled down, holding top rudder, to press for a shot, and he pulled up into me, shooting! I thought, "Oh, no maybe this guy isn't just lucky after all!" He used the same maneuver I had attempted, pulling up into me and forcing an overshoot—we were in the classic rolling scissors. As his nose committed I pulled up into him.
>
> In training I had fought in the same situation. I learned if my opponent had his nose too high, I could snap down, using the one G to advantage, then run out to his six o'clock before he could get turned around and get in range.
>
> As we slowed to 200 knots, I knew it was time to bug out. . . . The MiG's superior turn radius, coupled with higher available G at that speed,

started giving him a constant advantage. When he raised his nose just a bit too high, I pulled into him. Placing my aircraft nearly 180° to follow, Willie and I were two miles ahead of him, out of his missile range, at 600 knots airspeed.

With our energy back, I made a 60° nose-up vertical turn back into the pressing MiG. He climbed right after us, and, again, with the Phantom's superior climbing ability, I outzoomcd him as he squirted BBs in our direction. It was a carbon copy of the first engagement seconds earlier as we went into another rolling scissors.

Again we were forced to disengage as advantage and disadvantage traded sides. As we blasted away to regain energy for the second time, Irish came up on the [intercom], "Hey, Duke, how ya doin' up there? This guy really knows what he's doin'. Maybe we ought to call it a day."

This almost put me into a blind rage. To think some [bogey] had not only stood off my attacks but had gained an advantage on me twice!

"Hang on, Willie. We're gonna get this guy!"

"Go get him, Duke. I'm right behind you!"

Irish was all over the cockpit, straining to keep sight of the MiG as I pitched back toward him for the third time. Man, it felt good to have that second pair of eyes back there, especially with an adversary who knew what air fighting was all about. Very seldom did U.S. fighter pilots find a MiG that fought in the vertical. The enemy liked to fight in the horizontal for the most part, or just to run, if he didn't have the advantage.

Once again I met the MiG-17 head-on, this time with an offset so he couldn't use his guns. As I pulled up into the pure vertical I could again see this determined pilot a few feet away. Winston Churchill once wrote, "In war, if you are not able to beat your enemy at his own game, it is nearly always better to adopt some striking variant." My mind simply came up with a last-ditch idea. I pulled hard toward his aircraft and yanked the throttles back to idle, popping the speed brakes at the same time.

The MiG shot out in front of me for the first time! The Phantom's nose was 60° above the horizon with airspeed down to 150 knots in no time. I had to go to full burner to hold my position. The surprised enemy pilot attempted to roll up on his back above me. Using only rudder to avoid stalling the F-4 with the spoilers on the wings, I rolled to the MiG's blind side. He attempted to reverse his roll, but as his wings banked sharply he must have stalled the aircraft momentarily and his nose fell through, placing me at his six but still too close for a shot. "This is no place to be with a MiG-17," I thought, "at 150 knots . . . this slow, he can take it right away from you."

But he had stayed too long. We later found out that this superb fighter pilot, later identified as "Colonel Tomb" of the North Vietnamese Air Force, had refused to disengage when his GCI [ground-controlled intercept] controller ordered him to return to base. After the war we found out that "Tomb," presumably with 13 American aircraft to his credit, had to run for it if he were going to get down before flaming out.

He pitched over the top and started straight down. I pulled hard over and followed. Though I didn't think a Sidewinder would guide straight down, with the heat of the ground to look at, I called "Fox Two" and squeezed one off. The missile came off the rail and went straight to the MiG. There was just a little flash and I thought it had missed him. As I started to fire my last Sidewinder, there was an abrupt burst of flame. Black smoke erupted from the 17. He didn't seem to go out of control. . . the fighter simply kept descending, crashing into the ground at about a 45° angle.[2]

After the RQ missile, the next revolution in air combat was the development of truly dogfight-compatible all-aspect AAMs. Although all-aspect radar-guided missiles have been operational since the mid-1950s, it was not until the mid-1970s that these weapons had been perfected to the point where they were a factor to be reckoned with after the first pass of a visual dogfight. At about the same time there appeared all-aspect-capable heat-seeking AAMs. By this period most fighters, with or without guns, carried RQ missiles, and the more advanced fighters were sometimes adapted to (or were already compatible with) the new weapons. Thus, encounters between high-T/W fighters armed with all-aspect AAMs and low-wing-loaded aircraft having guns and RQ missiles are now possible.

For the high-T/W, high-wing-loaded fighter, the addition of all-aspect weapons greatly improves offensive potential. It is very difficult to obtain a good RQ shot against a better-turning target using the almost obligatory energy tactics, but these methods do allow a high-T/W fighter to generate high-aspect firing opportunities consistently. Unfortunately, these shots are most often of the look-down variety, which may limit their usefulness under many conditions.

Defensively, the high-T/W fighter pilot's job is made considerably more difficult by the inclusion of RQ missile armament in the opponent's arsenal. Zooms must be timed and performed more precisely, and the usual escape option of the energy fighter may no longer be available.

The pilot of a low-wing-loaded fighter in this case must be more careful of his energy state during the engagement. He can no longer afford the luxury of allowing the energy fighter to zoom with impunity to gain separation. Whenever the bogey zooms, the angles fighter pilot must either put a weapon in the air, even if only for effect, or immediately attempt an escape beyond visual range. It is even more critical in this scenario for the low-wing-loaded fighter pilot to follow the guidelines of angles tactics strictly; he must use nose-to-nose geometry to stay inside the bogey's min-range parameters, and he must remain below the opponent's altitude whenever he is positioned in the opponent's forward hemisphere.

At this time there do not seem to be any valid examples available of actual combat engagements in this scenario, although the potential certainly exists. There have been several conflicts in which these weapons mixes were matched, including the Gulf of Sidra incident (1981), the Falklands Conflict (1982), the Bekaa Valley encounters in Lebanon (1982), and the ongoing Iran-Iraq War. In all these cases, however, the high-T/W fighters equipped with all-aspect weapons also had at least parity in turn performance, if not outright superiority in instantaneous or sustained turn, or even in both. This scenario is covered in the next section.

Single-Dissimilarity Engagements

So far this chapter has discussed situations in which a low-T/W, low-wing-loaded fighter was pitted against a high-T/W, high-wing-loaded aircraft. This pairing might be termed "double dissimilarity," since there are significant differences in both of the critical performance parameters. Another likely situation is that the two fighters will be similar in one of these parameters but one aircraft will have a significant advantage in the other. For instance, both aircraft may have similar T/W, while one fighter has a significant wing-loading advantage; or both may have similar wing loading, but there is T/W disparity. These are examples of "single-dissimilarity" conditions.

Low versus High Wing Loading with Similar T/W

In this situation the low-wing-loaded fighter should enjoy a considerable instantaneous-turn-performance advantage, and also probably a significant sustained-turn superiority. Therefore, the pilot of such a fighter usually should base his tactics on this turn advantage and conduct an angles fight. Although T/W parity makes this an easier fight than that previously described for the low-T/W aircraft, it is not without danger. The low-wing-loaded fighter pilot still must be conscious of energy and not attempt to grab angles faster than his turn-performance advantage will allow. More aggressiveness is allowable because of the T/W similarity, but greed on the part of the angles fighter pilot will permit the opponent to use energy-based countertactics effectively. A good rule of thumb for the angles fighter pilot is to maintain at least vertical-maneuvering speed at each pass as protection against the opponent's possible zoom. Lower speeds are acceptable once the bogey has obviously bled its speed to the point where it lacks any significant vertical potential. Vertical-maneuvering speed for the low-wing-loaded fighter should be somewhat slower than for the high-wing-loaded adversary.

On the other side of this coin, the pilot of the high-wing-loaded fighter has a serious problem; namely, he has no performance advantage to exploit. In this case he usually should choose energy tactics, since there is at least parity in that area. He should recognize, however, that the opponent possesses the superior dogfighter and should win a one-versus-one fight, assuming the skills of the two pilots are equal. With this in mind, the energy fighter pilot should engage with the intention of evaluating the opponent's technique quickly, and then disengaging if he proves to be the Red Baron.

Because of the T/W equivalence, the climbing extension/pitch-back tactics described earlier generally are not viable. This method is based on exploiting a climb-rate superiority, which does not exist in this scenario. In order for the high-wing-loaded fighter pilot to gain an energy advantage where one does not exist initially, he must either increase energy faster than the opponent (which may be done by exploiting superior diving acceleration and high-speed energy addition rate in a diving extension), or induce the bogey to bleed energy at a faster rate (which may be accomplished by sustained-turn techniques). The latter method allows evaluation of the bogey's turn performance based on its known sustained capabilities relative to those of the high-wing-loaded aircraft.

For instance, assume that at optimum speed the high-wing-loaded fighter can sustain a 107sec turn rate, so that a 360° turn would require about 36 seconds to complete. If the bogey can sustain 117 sec at its optimum speed (a 10 percent advantage, which would be considered significant), it could gain about 30° in one nose-to-tail turn without losing a single knot of airspeed relative to the opponent. Grabbing greater angles advantages than this with each turn, however, requires the bogey to pay dearly with energy. Armed with this knowledge, the pilot of the high-wing-loaded energy fighter can assess his opponent's energy management by observing the bogey's angular gains. The energy fighter pilot should set up a nose-to-tail turn at maximum sustained-turn-rate speed (or vertical-maneuvering speed, if that is higher), either level or slightly nose-high. The bogey's nose position is closely monitored, and climb angle is adjusted to allow the bogey about a 90° angular advantage at the completion of one turn. If the bogey appears to be making angles too fast, the energy fighter pilot makes the transition to a nose-low turn, maintaining speed, to slow the opponent's angular gains. When, on the other hand, a bogey appears to be gaining little angular advantage in the turn, the climb angle can be steepened, reducing G to maintain speed, to allow the opponent to gain angles more rapidly.

If the bogey is pulling lead approaching the second pass (i.e., at the end of the first turn), the energy fighter pilot may be required to perform a quick out-of-plane guns-defense maneuver before beginning a vertical pull-up to trade his energy advantage for altitude separation at the overshoot. When an opponent uses lag pursuit approaching the pass, preserving nose-tail separation to minimize his overshoot, the spiral zoom will probably be necessary to deny the bogey a shot during the pull-up.

Against an all-aspect-missile-equipped adversary, the nose-to-tail turn technique may be unusable, since it can allow the bogey to satisfy min-range parameters during the first turn. In this case the energy fighter pilot may have to employ a less efficient nose-to-nose turn instead, using essentially the same procedures but reducing speed to the slowest value consistent with vertical-maneuvering potential. This slower speed keeps turn radius low, forcing the opponent to bleed more energy for angular gains. The nose-to-nose technique should help to hold separation inside the bogey's min-range limits, while bleeding its energy nicely. The pilot of the energy fighter should not allow this maneuver to continue into a repetitive flat scissors, however, since the low-wing-loaded opponent can make further small gains on each turn without bleeding additional energy.

An opponent who refuses to accept a large angular advantage on the first turn either is very nonaggressive or is playing it smart by using his turn-performance superiority to nibble away a few degrees at a time without bleeding energy. It may be difficult for the energy fighter pilot to determine which bogey is which, but "You pays your money and you takes your chances." The nonaggressive bogey can be beaten with angles tactics, so the usual procedure is to put one aggressive move on the bogey and check its reaction. A bogey that counters this move effectively should be left alone, and the pilot of the energy fighter should employ a nose-to-tail extension to separate and disengage. If the bogey's defense is inept, the attacking pilot should jump right into its knickers. Normally a rolling scissors should be avoided against a well-flown bogey, since the opponent will usually be better in this maneuver unless he is at a considerably lower energy state.

High versus Low T/W with Similar Wing Loading

In this scenario the high-T/W fighter should have an acceleration and climb-rate advantage as well as better sustained turn rate and faster top speed. Instantaneous-turn capability, however, should be similar. The pilot of a high-T/W fighter in this case can employ either angles or energy tactics, but angles methods are probably preferable since they are quicker, less complex, and more offensive. The angles fighter pilot can be quite aggressive in such a fight, since his T/W advantage offers insurance against an opponent's possible energy tactics.

If the high-T/W fighter pilot chooses the energy fight, climbing extension/pitch-back tactics are normally very effective, but other methods should also be useful. The energy fighter pilot can try to grab an initial angular advantage, then use lag pursuit and allow his sustained-turn superiority to bleed the bogey's energy in nose-to-tail turns. Once the opponent has neutralized the angular advantage, or gained a small one of his own, the energy fighter pilot can begin vertical maneuvering. The initial vertical move is generally a climbing spiral begun across the circle from the bogey. A wings-level vertical pull-up might also be workable, provided the bogey is equipped with guns only. Otherwise the wide lateral separation at the moment of the pull-up may allow the bogey to pull its nose up, point, and shoot as the energy fighter nears the top of its zoom.

Bleeding the bogey's energy by using offensive lag pursuit may take several turns, since it is up to the low-T/W opponent in this case to decide how fast he wishes to trade energy for angles. The bogey can prolong this fight considerably by turning nose-low, trading altitude for turn rate while maintaining speed. In this case the energy fighter pilot generally should follow the bogey down, maintaining a small altitude advantage, since the opponent can use the vertical separation for a zooming lead turn and a snapshot if the altitude differential is allowed to build too far. Likewise, diving on the bogey from a considerable height advantage tends to give back any energy margin gained, and may result in a vertical overshoot and a rolling scissors. Since the lower bogey has maintained speed and now has energy equivalence, it may gain a temporary advantage in this maneuver. Therefore, it is preferable simply to follow the bogey down from slightly above until it reaches low altitude and is forced to begin trading speed for turn rate. Once the bogey has been bled to a slow speed it will be much easier to handle.

A beautiful example of this process is found in an engagement between Baron Manfred von Richthofen (ten victories at the time) and the first British ace, Major Lanoe Hawker (nine victories), on 23 November 1916. The German was flying an Albatros D-II against the British de Havilland DH-2. The fighters were roughly equivalent in turn performance, but the Albatros had a significant climb and top-speed advantage. This is the way von Richthofen described the fight in his book *The Red Air Fighter*. (No dissenting version is available!)

> The Englishman tried to catch me up in the rear while I tried to get behind him. So we circled round and round like madmen after one another at an altitude of about 10,000 feet.

First we circled twenty times to the left, and then thirty times to the right. Each tried to get behind and above the other.

Soon I discovered that I was not meeting a beginner. He had not the slightest intention to break off the fight. He was travelling in a box which turned beautifully. However, my packing case was better at climbing than his. But I succeeded at last in getting above and beyond my English waltzing partner.

When we had got down to about 6,000 feet without having achieved anything particular, my opponent ought to have discovered that it was time for him to take his leave. The wind was favourable to me, for it drove us more and more towards the German position. At last we were above Bapaume, about half a mile behind the German front. The gallant fellow was full of pluck, and when we had got down to about 3,000 feet he merrily waved to me as if he would say, Well, how do you do?

The circles which we made around one another were so narrow that their diameter was probably no more than 250 or 300 feet. I had time to take a good look at my opponent. I looked down into his carriage and could see every movement of his head. If he had not had his cap on I would have noticed what kind of a face he was making.

My Englishman was a good sportsman, but by and by the thing became a little too hot for him. He had to decide whether he would land on German ground or whether he would fly back to the English lines. Of course he tried the latter, after having endeavoured in vain to escape me by loopings and such tricks. At that time his first bullets were flying around me, for so far neither of us had been able to do any shooting.

When he had come down to about 300 feet he tried to escape by flying in a zig-zag course, which makes it difficult for an observer on the ground to shoot. That was my most favourable moment. I followed him at an altitude of from 250 feet to 150 feet, firing all the time. The Englishman could not help falling. But the jamming of my gun nearly robbed me of my success.'

The pilot of a low-T/W fighter in such a scenario has definitely got his hands full, since he really has no performance advantage to exploit. He will have a very difficult *time* winning an energy fight against a pilot of similar ability, and an angles fight will be no picnic, either. However, his turn-performance equivalence (in instantaneous turns) favors angles tactics. This needs to be a fairly patient angles fight, using nose-to-nose turns and working below the bogey, as explained previously. If the opponent is able to gain too great an altitude advantage in a zoom to be threatened, the angles fighter pilot can attempt to gain separation by diving away and then coming back hard to meet the bogey nearly head-on to begin the fight anew. Escape is generally not available to the pilot of the slower fighter, unless he can cause his opponent to lose sight. Probably the most useful piece of equipment the low-T/W fighter pilot can have in such an engagement is a radio with which to call for help.[3]

Double-Superior and Double-Inferior Conditions

The quality of the box matters little. Success depends upon the man who sits in it.

Baron Manfred von Richthofen

A "double-superior" condition occurs when one fighter has both significantly higher T/W and lower wing loading than its opponent. Obviously the unlucky adversary in this situation is "double inferior."

> Only the spirit of attack borne in a brave heart will bring success to any fighter aircraft, no matter how highly developed it may be.
>
> Lt. General Adolph Galland, Luftwaffe

Double superiority is a condition for which a fighter pilot would gladly trade several semi-essential parts of his anatomy. A double-superior fighter has the speed and acceleration to force an opponent to fight, and the maneuverability to win the fight. In such a situation the superior fighter generally should choose angles tactics, for a variety of reasons. This method is generally quicker and easier, and it facilitates maintaining sight and allows the opponent fewer weapons-firing opportunities and less chance of escape. The pilot of the superior fighter can be quite aggressive in this scenario, using his turn performance to gain advantage and relying on his power to keep him out of trouble. Lower minimum vertical-maneuvering speed and higher Ps provide a measure of safety against the bogey's possible energy tactics, but the angles fighter pilot can still lose this fight if he tries hard enough. If he races around with fangs out and hair on fire, with total disregard for energy, he may allow even an inferior opponent to gain a substantial energy advantage and convert this to a temporary but lethal position advantage. This usually can be avoided by allowing the superior aircraft to do the job at its own pace, which normally will be fast enough. Aside from overaggressiveness on the part of the pilot, speed control is the superior fighter's greatest problem. Excess power often results in excess speed and a tendency to overrun or overshoot the adversary. Under the best of circumstances such overshoots prolong the fight, which, particularly when missiles are involved, may be fatal. Judicious use of power is the key here. In the sterile, one-versus-one engagement, the pilot of the superior fighter normally should attempt to keep his speed the same as or slightly below that of his opponent.

The pilot of the inferior fighter in this scenario has real problems. He may not be able to avoid engagement, and he may not be able to escape once he is engaged. These problems may be alleviated, however, by a very thorough aircraft preflight inspection, followed by a decision to spend the day in the bar. If this luxury is not available, high-speed hit-and-run tactics or multiple-aircraft engagements may offer some relief; otherwise the pilot of the inferior fighter must be very good and very lucky.

> If he is superior then I would go home, for another day that is better.
>
> Colonel Erich "Bubi" Hartmann, GAF

With an inferior aircraft, victory in one-versus-one combat must come through superior tactics and better technique. Because energy tactics are so much more complex than angles tactics, they tend to magnify variations in pilot ability. This is one reason energy tactics are recommended for this scenario. Another factor is the increased time involved. Besides prolonging the agony, energy techniques may allow the pilot of the inferior fighter to hold the opponent off until he loses interest or is forced to withdraw for fuel considerations. The high-G descending nose-to-tail turn is ideal for this purpose. If the opponent is equipped with RQ missiles, this tactic may allow the pilot of the inferior fighter to hold the bogey just far enough off the tail to prevent a weapons firing while he unexpectedly reduces power or uses speedbrakes to slow down and thereby generate rapid closure with the opponent. Then at the critical moment he can make a break turn toward the bogey to produce an overshoot. If the bogey pilot does not recognize this ploy soon enough and immediately quarter roll away and pull up, the inferior fighter may be able to reverse for a cheap shot. If the bogey does pull up nearly vertically, the defender may have a chance to unload and accelerate down and away, generating separation to prolong the fight, or even causing the bogey pilot to lose sight. When the bogey is gun equipped, the defender should expect a snapshot prior to the overshoot and be prepared to defeat it with a sharp, out-of-plane jink.

Climbing extension/pitch-back tactics cannot be expected to work for the inferior fighter in this scenario, since the opponent has a Ps advantage. The other energy tactics discussed, which are intended to bleed the bogey's energy with a nose-to-tail turn (or nose-to-nose in the case of a very small bogey or one equipped with all-aspect missiles), can still be effective against an inexperienced or a careless opponent.

The following episode, found in *Thunderbolt!* by the World War II USAAF ace Robert S. Johnson, is one of the best examples available of the use of energy tactics (diving extension/pitch-back) to defeat a double-superior opponent. The encounter described is a mock combat engagement over England between Johnson (P-47C) and an unidentified RAP pilot in a new Spitfire IX. The Spitfire had about a 25 percent better power loading and nearly a 25 percent lower wing loading. The Thunderbolt's only performance advantages were faster top speed, greater acceleration in a dive (because of the P-47's heavier weight and higher density), and better roll performance. (See the Appendix for a discussion of roll and acceleration performance.) Johnson, undoubtedly one of the greatest natural fighter pilots of all time, used his roll performance defensively to allow himself the chance to build an energy advantage in a diving extension.

> We flew together in formation, and then I decided to see just what this airplane had to its credit.
>
> I opened the throttle full and the Thunderbolt forged ahead. A moment later exhaust smoke poured from the Spit as the pilot came after me. He couldn't make it; the big Jug had a definite speed advantage. I grinned happily; I'd heard so much about this airplane that I really wanted to show off the Thunderbolt to her pilot. The Jug kept pulling away from the Spitfire; suddenly I hauled back on the stick and lifted the nose. The Thunderbolt zoomed upward, soaring into the cloud-flecked sky. I looked out and back; the Spit was straining to match me, and barely able to hold his position.
>
> But my advantage was only the zoom—once in steady climb, he had me. I gaped as smoke poured from the exhausts and the Spitfire shot past me as if I were standing still. Could that plane *climb!* He tore upward in a climb I couldn't match in the Jug. Now it was his turn; the broad elliptical wings rolled, swung around, and the Spit screamed in, hell-bent on chewing me up.

> This was going to be fun. I knew he could turn inside the heavy Thunderbolt; if I attempted to hold a tight turn the Spitfire would slip right inside me. I knew, also, that he could easily outclimb my fighter. I stayed out of those sucker traps. First rule in this kind of a fight: don't fight the way your opponent fights best. No sharp turns; don't climb; keep him at your own level.
>
> We were at 5,000 feet, the Spitfire skidding around hard and coming in on my tail. No use turning; he'd whip right inside me as if I were a truck loaded with cement, and snap out in firing position. Well, I had a few tricks, too. The P-47 was faster, and I threw the ship into a roll. Right here I had him. The Jug could outroll any plane in the air, bar none. With my speed, roll was my only advantage, and I made full use of the manner in which the Thunderbolt could whirl. I kicked the Jug into a wicked left roll, horizon spinning crazily, once, twice, into a third. As he turned to the left to follow, I tramped down on the right rudder, banged the stick over to the right. Around and around we went, left, right, left, right. I could whip through better than two rolls before the Spitfire even completed his first. And this killed his ability to turn inside me. I just refused to turn. Every time he tried to follow me in a roll, I flashed away to the opposite side, opening the gap between our two planes.
>
> Then I played the trump. The Spitfire was clawing wildly through the air, trying to follow me in a roll, when I dropped the nose. The Thunderbolt howled and ran for earth. Barely had the Spitfire started to follow—and I was a long way ahead of him by now—when I jerked back on the stick and threw the Jug into a zoom climb. In a straight or turning climb, the British ship had the advantage. But coming out of a dive, there's not a British or a German fighter that can come close to a Thunderbolt rushing upward in a zoom. Before the Spit pilot knew what had happened, I was high above him, the Thunderbolt hammering around. And that was it—for in the next few moments the Spitfire flier was amazed to see a less mancuverable, slower-climbing Thunderbolt rushing straight at him, eight guns pointed ominously at his cockpit.[4]

V/STOL and Helicopter Tactical Considerations

Progress in aviation and weapons technology has begun to result in several types of "unconventional" fighter aircraft. Among these are vertical/short -takeoff and -landing (V/STOL) fighters, and helicopters.

V/STOL versus Conventional Fighters

There are currently two distinct variations in V/STOL design. The first of these to be considered is the thrust-vector type, typified by the British Harrier. This design has four jet exhaust nozzles that can be pivoted to direct the exhaust directly astern, or downward, or even slightly forward. Two nozzles are located behind and two forward of the CG, so that the aircraft can be supported in a hover by the four downward columns of jet exhaust, much like the legs of a four-poster bed. The Harrier has only a single engine, but fighters of this type with multiple engines could follow. While it is at very slow speeds the fighter's attitude is controlled by small reaction jets of engine bleed air located in the nose and/or tail and on the wing tips.

In order to takeoff and land vertically, this fighter must have a T/W of greater than 1. When the aircraft is heavily loaded with fuel and ordnance, however, weight may exceed thrust; in this case the aircraft requires a short horizontal run and assistance from the wings to get airborne or to land safely. Also, since jet thrust is diminished by high altitude or hot temperatures, horizontal takeoff and landing runs may be required under some operating conditions, even at low weights. Still, the short-takeoff and -landing capability allows operations to take place from short, makeshift airfields in forward battle areas, from battle-damaged runways, and from the decks of ships.

The second type of V/STOL fighter is the lift-fan design, such as the Russian Yak-36 Forger. This type incorporates one or more (two in the Forger) lift jets that exhaust only downward; these are used in conjunction with the main engine(s). The primary engine of the Forger has two pivoting exhausts located in the rear, much like the Harrier, to vector the thrust downward or aft. The lift jets support the front of the aircraft and the main engine supports the rear during a hover.

The added capabilities of V/STOL fighters are not achieved without penalties. The primary limitations of these designs are short range and low ordnance-carrying capability in comparison to conventional fighters of similar technological level. The requirement for high thrust and low weight leaves little margin for large structures, great amounts of fuel, or large ordnance loads. Such fighters, therefore, are usually small, lightly armed, and lightly armored, with limited radius of action and combat endurance. Although T/W and wing loading must be compared to those of an opposing aircraft for them to have much relevance to fighter performance, some generalizations can be made. Since improved landing and takeoff performance is provided by a vertical thrust component, large wings are unnecessary. In addition, large wings reduce high-speed performance and add weight, so V/STOL fighters tend to have relatively small wings and high wing loading, which can degrade turn performance. Even so, inherent high T/W generally keeps sustained turn performance rather high. Instantaneous turn performance, however, is likely to suffer because of high wing loading.

Some V/STOL fighters can improve their instantaneous turn performance through a technique known as "VIFFing" (vectoring in forward flight), in which thrust vectoring can be used to assist the wings. By pointing the exhaust downward (relative to the aircraft), thrust vectoring increases instantaneous load factor by about 1 G. Under slow-speed, low-G conditions this feature might double instantaneous turn performance, but at high speed and high G its effect would be minimal. This increased turn performance also must be paid for, however. Since essentially all the thrust is directed downward, there is no forward component to oppose drag, and therefore the aircraft will decelerate even faster than a conventional fighter performing a similar maneuver. The V/STOL fighter operating in this way needs all that good T/W to accelerate out of its energy hole after the turn.

Not all V/STOLs have the option of using thrust vectoring in this manner. In particular, the lift-jet designs often have intake covers that open outwardly to deflect air into the lift fans. These deflectors may have airspeed limitations, and if not, they would certainly act as speedbrakes, further increasing deceleration. Another problem with the lift-fan/lift-jet design is fuel flow. Cranking up those jets for a magic turn can double total fuel flow and greatly decrease combat endurance. The lift jets usually are intended for use during takeoff and landing, and they must be carried as dead weight during the rest of the mission. This feature generally increases aircraft weight and decreases fuel storage space, and it also may result in installation of a smaller main engine. All these handicaps tend to reduce T/W and the combat endurance of the lift-jet V/STOL variety, which is usually inferior to the pure thrust-vector type.

The unique characteristics of the V/STOL fighters make them well suited to energy tactics. Their good sustained turn, acceleration, and zoom capabilities can be capitalized on by energy methods. Some models are able to vector exhaust nozzles well forward for use as airborne thrust reversers. This feature provides very rapid deceleration and, possibly in conjunction with increased instantaneous turn performance, may be useful in preventing or causing overshoots. Rapid deceleration is also invaluable in the early stages of a flat scissors or a defensive spiral. Normally, VIFFing should be reserved for such defensive or terminal-offensive situations.

One glaring exception to this rule, however, is the vertical reversal after a zoom climb. If the rear nozzles can be deflected downward (toward the belly of the aircraft) while the fighter is near vertical in a slow-speed zoom climb, the aircraft can be made to pitch forward and "swap ends" very quickly to point down at the bogey. Alternatively, thrust vectoring may be used to increase G over the top of a more conventional looping maneuver. This capability, as well as the usually fine sustained turn performance and good slow-speed control, also can make this a very mean opponent in a rolling scissors. All these attributes, and small size, often result in a very fine energy fighter; but energy tactics and the added complexity of operating this type of aircraft require highly skilled pilots and extraordinary air-to-air training.

The ability to swivel rear-mounted exhaust nozzles of a fighter upward relative to the aircraft makes a V/STOL or other thrust-vector fighter more compatible with angles tactics. When combined with an airframe that is well behaved at a high angle of attack, VIFFing, much like the thrust-vector control system discussed earlier for missiles, can cause a fighter to pivot about its CG and literally swap ends at virtually any airspeed. The ability to point quickly in any direction can be extremely valuable, particularly when the aircraft is equipped with all-aspect missiles. Again, however, such thrust-vector maneuvers should be used judiciously because of the rapid energy dissipation that results.

The hover capability of the V/STOL is often highly overrated in the air-to-air environment. First of all, most V/STOLs lack hover capability at realistic operating weights and altitudes. Even if these aircraft could stop in midair, attitude control is usually not adequate for aiming boresight weapons at an enemy fighter unless the bogey flies in front of the weapon. Off-boresight weapons may make this tactic slightly more feasible; but still, a motionless aircraft presents an all-aspect heat source and is a sitting duck for nearly any weapon in the enemy's arsenal, either air-to-air or surface-to-air. (The Doppler radar-guided AAM is a notable exception to this rule.)

For a conventional fighter opposing a V/STOL, angles tactics usually will be more appropriate. The angles fighter pilot must be mindful of the V/STOL bogey's ability to generate overshoots and be ready to quarter roll away and pitch off high in case the V/STOL slaps on a "bat-turn." In such a case the bogey pilot has most likely forfeited his vertical capability for increased turn performance, so the angles fighter pilot should find a safe sanctuary at higher altitude, provided he has practiced good energy management himself. If the pilot of the angles fighter allows himself to get well below vertical-maneuvering speed, such an overshoot probably will result in a flat scissors, placing him in deep and serious kimchi. The rolling scissors also should be avoided unless the V/STOL bogey is obviously low on energy, like after a magic turn; and a defensive spiral must be rejected at any cost. In short, the pilot of the conventional fighter often will obtain the best results from the early use of careful angles tactics to keep pressure on the V/STOL bogey and deplete its energy. Then, when the V/STOL pilot decides to use his VIFFing ability for slow fighting, the angles fighter pilot can revert to energy tactics. If the engagement cannot be ended quickly, and the bogey is allowed to regain its energy, it may be necessary for the pilot of the conventional fighter to resume angles tactics once more.

Helicopters versus Conventional Fighters

Although helicopters generally have not been considered air-to-air machines in the past, many current attack helos are heavily armed and can offer some interesting problems to fixed-wing fighters. When compared with conventional jet fighters, helos are so slow they can't get out of their own way, so they simply do not have the capability to seek out and offensively engage faster aircraft. Therefore, engagements are most likely to occur while the helo is out minding its own business, or making life miserable for enemy ground forces. Although the helo probably will be the attackee rather than the attacker at the start of the engagement, a well-flown helicopter is far from defenseless.

> The primitive can also be a weapon.
>
> Lt. General Adolph Galland, Luftwaffe

One of the helo pilot's first defensive actions when he is faced with a fixed-wing attack is to dive to as low an altitude as possible and accelerate to max-speed while turning toward the attacker. This reaction serves many purposes. Very low altitude operation degrades the bogey's weapons systems by denying its pilot the look-up necessary to optimize radar operation and the guidance capabilities of heat-seeking and radar-guided missiles. Simply flying at low level is sufficient to defeat most pulse-type radars, which cannot distinguish the target from the ground return (clutter). Although sophisticated pulse-Doppler (PD) radars are theoretically capable of detecting and tracking a low-flying target, their operation usually will be degraded by a "jamming" effect inherent to the helicopter rotor. Since the PD radar sees only moving objects, the real target will appear to be surrounded by many other "targets," as each of the rotor blades alternately increases and decreases its speed over the ground with every revolution. A Doppler radar and missile normally will have great difficulty maintaining a steady track on the helo itself with all this distraction, which can result in erratic guidance, increasing miss distance, and possibly missile-ground impact. This phenomenon also plays havoc with most Doppler-rate fuzes, causing early fuzing and warhead detonation. Active fuzes have problems in this environment, too, as they are susceptible to detonation on ground return before detecting the target. When the attacker's primary weapon is known to be a Doppler-type radar missile, the helo pilot may choose to fly at roughly right angles to the bogey's approach, which (as described in Chapter 1) should eliminate the primary radar return completely, or at least hide it in the ground clutter. This tactic leaves only the rotor blades as radar targets and further complicates the missile's task. Hovering motionless would serve the same purpose, but that tends to make the helo highly vulnerable to other weapons.

Flying toward the attacker has other benefits. The increased closure reduces the bogey's firing time for either guns or missiles, and if the attacker attempts to track the helo visually to fire a boresight weapon, the moving target causes the shooter to steepen his dive angle rapidly. This is a very uncomfortable maneuver for the pilot of a high-speed fighter close to the ground, and it often causes the attacker to break off a firing pass before reaching his most effective range. Pointing at the attacker also tends to hide the helo's jet exhaust from a heat-seeking missile.

Low-level flying is the bread and butter of most helo drivers, and they are very comfortable in this environment. Not so with the average fighter jock, who is likely to be quite uncomfortable attempting to bring weapons to bear against a moving, highly maneuverable, low-level target. This factor is of great advantage to the helo. The helo pilot also should be aware of the background he is presenting to his opponent and use any available opportunity to make things as difficult as possible for the bogey. This can be done by positioning over variegated terrain, which blends most closely with the helo's color scheme. Dark camouflage over dark terrain works best, since shadows may tend to highlight the low-flying helo on sunny days over a light-colored surface. Mottled terrain is usually more effective than uniform colors, unless the aircraft camouflage matches the terrain very closely. Trees, shadows, and hills can also be very useful hiding places. Water, tall grass, and dusty areas usually should be avoided because of rotor effects on these surfaces. At best, low-flying aircraft are very difficult to spot and track visually. With a little effort they can be made almost invisible.

The helo pilot should also attempt IR masking when he is faced with a heat-seeking missile threat. Visual masking and IR masking are often mutually exclusive, however, since hot, usually light-colored desert backgrounds offer the greatest problems for IR missiles. Such unlikely surfaces as water and snow can also be quite effective reflectors of IR energy, particularly if the bogey is attacking toward a bright sun.

As a fighter, the helicopter is the very epitome of a low-T/W, low-wing-loaded aircraft, being blessed with exceptional turning capability but very poor energy performance when compared with fixed-wing fighters. Therefore angles tactics, as described earlier in this chapter and in Chapters, can be applied by the helo in their purest form. Helo weapons useful in the air-to-air arena most often include flexible guns, manually aimed or turret-mounted; fixed, forward-firing guns; unguided rockets; and heat-seeking AAMs. A helo's gunsights, however, are seldom optimized for the air-to-air arena, so unguided weapons require lots of Kentucky windage for use against high-speed fighters.

Once the immediate priorities of getting to low altitude and turning toward the attacker have been accomplished, the helo is faced with defeating any possible firing attempt made by the bogey prior to the first pass. The attacker's job is made more difficult if the helo is not flown directly toward the bogey, but at an angle of 30° to 45° instead. This tactic forces the attacker to turn in order to establish lead for a gun shot, unguided rockets, or bombs (that's right, bombs!), or to track with a boresight missile. Once the bogey is established on the proper heading for releasing its weapon and is approaching firing range, the helo should turn sharply toward the attacker and pull him across the nose to the opposite side. This forces the bogey to turn in order to reestablish the proper lead or boresight heading. As the attacker approaches the proper heading again, the helo can pull him across the nose once more, keeping the attacker's nose out of phase and spoiling the shot. One or two of these jinks should be all that are required before the bogey reaches minimum firing range. Helos equipped with forward-firing, turret-mounted guns may be able to bring the attacker under fire during much of his approach, even during this jinking process. The opportunity to fire an all-aspect missile head-on should not be passed up either, probably as the bogey crosses the nose during a jink. The helo's look-up angle should provide better target discrimination, making this shot more effective than the similar, but look-down, firing by the attacker. A few dozen unguided rockets thrown up in front of the attacker prior to the pass can also have a startling effect on his marksmanship.

> Being under Hre is bad for the nervous system.
>
> Captain Willy Coppens
> Leading Belgian Air Force Ace, WW-I
> 37 Victories (36 of Which Were Tethered Balloons)

Although no self-respecting fighter pilot would carry a bomb, there is no telling what kind of low-life may be met over a battlefield, so such an attack must be considered. Should some sort of ballistic projectile be seen falling from the enemy aircraft, the helo should immediately turn away from the predicted impact point and make tracks to gain separation as rapidly as possible. The chances of actually being hit by such a bomb are small (especially when it is dropped by a fighter pilot), but the fragments from typical bombs can be lethal more than 2,000 ft from the point of detonation.

Approaching the pass, the helo pilot should try to generate some flight-path separation and lead-turn the bogey, as recommended for the angles fighter in previous scenarios. Because of the helo's very tight turn radius, even minimal lateral separation can be converted to large angular gains at the pass. If the bogey continues straight or pulls up after the pass, the helo driver can continue to pull the nose around for a shot before the target extends out of range. Should a shot at this point be unsuccessful, and the bogey exceeds max-range, the helo pilot might think of making a break for some protected area or hiding place. If such a safe haven is not available, or if the helo driver begins to like playing fighter pilot, he may choose to pursue the bogey, wait for it to turn around, and repeat the head-on pass tactics. Unless the helo pilot has considerable air-to-air experience, however, this is probably a mistake.

If the bogey pulls sharply vertical at the pass and the helo pilot cannot make a shot, he should follow the attacker at low altitude and attempt to get beneath the bogey as it completes the vertical maneuver. This ploy makes a second attack by the bogey more difficult, since it would necessitate a steep dive angle. Pilots usually will avoid steep dives at low altitude for fear of misjudging the pull-out and hitting the ground. As the bogey approaches overhead, the helo can pull up in an oblique climbing turn beneath the attacker for a look-up, RQ weapons firing, or it can at least hide beneath the opponent, forcing him to turn hard to regain sight.

Returning to the first pass for a moment, if the fixed-wing bogey turns hard toward the helo, taking out most of the lateral separation and preventing an effective lead turn, the helo might have trouble turning around fast enough to get a shot. If this happens, the helo can continue the classic angles tactics illustrated by Figure 3-1; that is, reverse nose-to-nose. In this case, however, there is such a large disparity in speed and turn radius that a simple reversal and a level nose-to-nose turn should quickly place the helo inside the opponent's flight path, making it impossible for the pilot of the fixed-wing fighter to get his nose pointed at the helo for another attack. The helo pilot should continue the turn for at least 90°, then straighten out or reverse into a gradual lead turn, maintaining 20°-30° of lead on the bogey. Care should be taken not to turn so hard in the lead turn that the helo flies out in front of the bogey. This situation can be anticipated by watching the bogey's drift against the far horizon, and ensuring that this apparent motion is always forward. Ultimately, if the bogey continues its turn, the helo pilot can play his lead turn to arrive at a close-range gun-firing position or within RQ missile parameters. An all-aspect-missile-firing opportunity may be available soon after completion of the nose-to-nose turn, provided min-range parameters can be met.

Now for the other side of this coin. How does a fixed-wing fighter attack a helo? It has been shown that a helo can be a very difficult opponent, but the fixed-wing fighter does have some advantages that can be exploited. For one thing, odds are the helo driver has very little air-to-air experience, so he may not be as serious a threat as the foregoing discussion might suggest. Still, caution and deviousness form the best policy.

First there is the matter of what weapons to use, given the fighter pilot has a choice. The gun can be very effective against helos, particularly when the attack is unseen; but, as discussed, scoring against an evasive helo can be quite difficult and may subject the fighter to return fire. In addition, most radar lead-computing gunsights are more than worthless in this environment because of ground clutter and rotor-blade effects. The attacker may find a simple fixed sight more effective, especially at low altitudes. Stories are told of an Israeli fighter pilot who made eight gun passes on a helo before switching to a fixed gunsight for the kill. Unguided rockets, fired in large salvos, can be lethal weapons, since greater dispersion increases the probability of a hit, and increased firing range can keep the attacker outside the helo's effective guns range. The helo pilot's not likely to do much shooting anyway once he sees a flock of rockets headed his way! Rockets fired singly, however, offer little chance of success.

Although any real fighter pilot hates to admit it, bombs may be the best low-altitude anti-helo weapon. The kill mechanism here is not necessarily a direct hit, which would be very difficult to achieve against an evasive target, but the rather large fragmentation pattern. With a typical 500-lb bomb, a 500-ft miss would probably be sufficient to do some damage to a low-flying (i.e., below 1,000 ft) helicopter. Even this degree of accuracy is not easy to achieve, however, against a moving, evasive target that must be led considerably when the bomb is released. Retarded bombs are usually best for this purpose. (Retarded does not relate to the bomb's intelligence level, but refers to high-drag devices that retard the bomb's speed after its release, allowing the bomber greater separation from the frag pattern before weapon impact.) Retarded weapons allow the bomber to release much lower and closer to the target for improved accuracy, and their shorter time of fall (because of a closer release) allows the target less time for evasive action. Although such close releases may bring the fighter within the target's gun range, the helo pilot is likely to lose all offensive intentions once the bomb is in the air.

One notable exception to this technique occurs when the helo is equipped with all-aspect heat-seeking missiles. In this case a low-altitude bomb run at high speed and power setting may allow the helo a forward-quarter, look-up missile shot before the fighter reaches the bomb-release point. A better method of attack would be to approach the helo at high altitude and low power setting, well above its missile's max-range, then make a steep dive-bombing run at idle power, at least until inside the threat missile's min-range. After release of the bomb or bombs the fighter should make a low-altitude pull-out and extend at high speed and low level out the bogey's extended six o'clock. Afterburners, which increase the fighter's IR signature by an order of magnitude, should not be required after a dive from high altitude and should not be used. Low-drag (unretarded) bombs are generally best for this tactic because of reduced time of fall from a high release. With either retarded or low-drag bombs, fuzes set to explode instantaneously on ground impact, or even slightly before, are optimum because of the resulting frag-pattern increase.

Cluster bombs (bombs that dispense large numbers of small "bomblets" after release) can also be effective against helos, but they are usually inferior to general purpose bombs for this mission because of the greatly reduced frag pattern of the cluster weapon. Although this "shotgun" weapon makes a direct hit more likely, a direct hit would probably be required to destroy the target, and it would still be quite difficult to achieve against an evasive helo. The cluster bomb would be better than general purpose bombs against a helo at high altitude, but other air-to-air weapons would probably be more appropriate in that case.

AAMs may also be viable weapons against the helo. The radar-guided weapons, however, have serious problems, as noted earlier, and probably would be rather ineffective, especially against a low-altitude target. A Doppler-guided missile might have a chance if it was employed in a low-level, head-on attack, so that the helo's closing speed would aid the missile in distinguishing the target from ground clutter. Side-lobe clutter, as described in Chapter 1, is the problem with RQ attacks with this weapon, and it may necessitate a higher-altitude, shoot-down launch.

Heat seekers are much better suited to this scenario, but they still are not without problems. Helicopters often have exhaust shields that reduce their IR signatures, and hot exhaust gases may be dispersed by the rotor wash. In a look-down environment, especially over hot desert terrain, RQ-only heat seekers may be more effective than their all-aspect counterparts because they are less sensitive to background IR radiation. RQ heat-seeking missiles should be fired whenever the target heat source can be detected, regardless of aspect. Even "RQ" AAMs may have all-aspect capabilities against slow aircraft that are unable to generate high speed or a high load factor.

If all else fails, a high-speed pass very low over the top of the helo is very likely to disrupt airflow through the rotor blades sufficiently to cause a loss of control, and can drive a low-altitude helo into the ground.

Probably the best tactic to employ against a helicopter is to sneak up on it and attack with bombs, guns, unguided rockets, or IR missiles. If detected by the target, about the best the pilot of a fixed-wing fighter can hope for is a head-on pass. Turning with a helo is fruitless and can be downright dangerous. If the first attack is not successful and multiple runs are necessary, a variation of extension tactics can be used. On each pass the fighter pilot should turn hard toward the helo to reduce lateral separation to a minimum, then extend at low altitude and high speed, turning in the nose-to-tail direction only as necessary to keep sight of the helo behind. If the helo is missile equipped it is important both to stay low to avoid giving the bogey any look-up and to cease use of afterburners before the bogey can complete its turn and fire. The combination of high fighter speed, low altitude, and the slow speed of the helo all work to reduce the helo missile's max-range to probably half that advertised for fighter engagements at higher altitudes. Against non-missile-equipped helos, a gradual climb may be more comfortable during the extension.

The extension should be continued until the fighter is well outside the helo's missile range, and until the fighter can make a reversal to meet the helo again head-on and still have sufficient separation for gun, missile, or bomb-sight tracking. A power reduction and a nose-high oblique reversal may allow the fighter pilot to tighten his turn and get the nose around quicker. The length of the extension may be reduced by the requirement to keep sight of the helo, and tracking times may be short as a result. If two fighters are available, one can orbit around the fight high, keeping track of the helo and directing the engaged fighter pilot in case he loses sight of the bogey. Or both fighters can engage the helo simultaneously from different directions. Caution is required, however, when the fighters are dropping bombs, as the frag pattern from one bomb must be given time to dissipate before the second fighter enters the area.

In general, except for the comments on rotor-blade effects, the tactics and considerations outlined here are relevant to most low-altitude engagements between fighters with very great disparity in performance.

Notes

1. John T. Godfrey, *The Look of Eagles,* pp. 98-99.
2. Randy Cunningham, -Fox *Two,* pp. 104, 106-8.
3. Manfred F. von Richthofen, *The Red Air Fighter,* pp. 84-85.
4. Robert S. Johnson, *Thunderbolt!* pp. 148-49.