Important Information

Use the following guidance and tests to determine whether your computer is compatible with the animation and movie software utilized in the development of this volume. Print these instructions for reference purposes before attempting to conduct animation test or install/uninstall video software.

Animations on this AFTTP 3-3 volume were created for Briefing Room Interactive (BRI) which requires a monitor capable of displaying 1024x768 resolution. In order to view these animations, you will need to set your monitor resolution to a minimum of 1024 x 768. To change monitor resolution, follow these steps on a Windows NT machine (these steps may vary depending on the version of Windows installed and type of monitor used on your machine):

1. To test, click on **animation**
2. If you can view the entire page, such that you can see control buttons at the bottom of the screen allowing you to play the animation, your resolution is correct.
3. If you can not see the full page, but only the upper left portion with no control buttons at the bottom, you need to change your monitor resolution. Continue with these steps.
4. Hit Escape on your keyboard to exit the animation
5. Close or minimize the Vol5.pdf file so the desktop is visible.
6. Right-click somewhere on the desktop
7. Select Properties
8. Select the Settings tab from the Display Properties window
9. Adjust slide bar in desktop area to 1024 x 768 pixels
10. Click Test
11. If Test passes, select Yes, then OK
12. If Test doesn't pass, your configuration does not support this resolution. You will not be able to run the animations.

Movie files on this volume are digitized HUD events supplied by an external agency and are not compliant with the ISO MPEG 1 standard. As such, viewing these movies may not be possible depending on your software configuration. You may already have compatible movie player software installed on your machine. If you do, the videos will play without adding additional software.

1. To test a video, click on **video**
2. If you get an error message, or the video does not run, install Microsoft Media Player, using the button on the next page.
3. If MS Media Player does not install, check to ensure you have Internet Explorer 4.0 or newer.

4. If your computer does not have Internet Explorer 4.0 or newer, install it using the button below before attempting to install MS Media Player.
5. After installing MS Media Player, restart the computer and repeat step one to test a video.
6. If the video still doesn't run, you may have a conflict between MS Media Player and an existing movie player already on your computer, such as QuickTime.
7. If so, uninstall all other movie players loaded on your computer. Note: After viewing the movies in this volume, it may be necessary to reinstall previous movie player software and uninstall MS Media Player to view movies obtained from other sources.
8. Once uninstall is complete, repeat step one to test a video. If the videos still won't play, then reinstall MS Media Player and restart the computer.
9. Repeat step one to test a video.

Note: MS Media Player and Internet Explorer 4.0 are designed to run in Windows 95/98/NT4.

If you have a Macintosh, the movies should play fine. If you have trouble viewing videos, download QT4 for Mac from the Apple web site.

UNIX users unable to play movies should contact their UNIX software provider to get compatible software.

Install Media Player	Install IE 4.01 (Win 95 or NT 4)

ROYAL NORWEGIAN AF TACTICS, TECHNIQUES & PROCEDURES 3-3

VOLUME 5

BASIC EMPLOYMENT MANUAL F-16AM

15 April 2001

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ROYAL NORWEGIAN AF TACTICS, TECHNIQUES AND PROCEDURES 3-3
15 APRIL 2001
VOLUME 5

BASIC EMPLOYMENT MANUAL - F-16AM

PURPOSE: The Air Force Tactics, Techniques, and Procedures (AFTTP) 3-3 series publications are the primary aircraft fundamental reference document for the USAF. This special version of AFTTP 3-3 was prepared specifically for the Royal Norwegian Air Force and is based on the most current version of USAF F-16 fundamental employment procedures and techniques. This series provides a comprehensive, single-source document containing fundamental employment procedures and techniques necessary to accomplish the various missions. The procedures and techniques are presented solely for consideration in planning and are not for regulatory purposes. Other procedures and techniques may be used if they are safe and effective; the fundamentals presented are solely for employment and planning considerations.

SCOPE: This manual addresses basic flying tasks and planning considerations for the air-to-air (A/A) and air-to-surface (A/S) arena. It presents a solid foundation on which effective tactics can be developed. This manual is not a step-by-step checklist of how to successfully employ aircraft, but rather it provides information and guidelines on basic procedures and techniques.

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CHAPTER 1

INTRODUCTION

1.1. Overview. War in the aerospace environment is currently in a period of fast-paced evolution. Since the beginning of aerial combat, technological development has driven, and been driven by, progress in building more efficient and effective aircraft and weapons. Nevertheless, the very basic principles of aerial combat have remained virtually unchanged. As technology advances, mutual support and situational awareness (SA) are still critical to effective employment of airborne weapons. Current data link systems and situational displays will not reduce the need to stick to the basics. These fundamentals, or standards, are only part of training for combat, and provide the building blocks for effective tactical employment. Discussions on formation flying, air-to-air (A/A), air-to-surface (A/S), and night operations in the F-16 are designed to aid in building a strong foundation of tactical skills. The maneuvers addressed are a means to an end, a starting point for pilots to study and explore first hand, and describe the methods used to achieve desired results in air combat training (ACT) and surface attack tactics (SAT).

1.2. Purpose. This manual is designed to supplement training programs; and when used in conjunction with Advanced Employment Manual, 3-1, Volume 5, provides F-16 pilots the information needed to make the right decisions during any phase of a tactical mission. This manual is not directive in nature, and provides no authority to depart from established training procedures.

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CHAPTER 2

PREPARATION

2.1. Introduction. Mission preparation is absolutely essential for successful fighter operations. A common understanding of what is expected during all phases of mission employment allows all fighters to concentrate on mission objectives. It provides the foundation for performance enhancing knowledge and skills encompassing: situational awareness (SA); flight integrity and effective communication; task and risk management; and mission planning and debriefing. Each aspect is part of a professional, disciplined approach to increase flight safety and maximize combat capability.

2.2. Preparation.

2.2.1. Psychological Considerations. Fighter missions demand total involvement. This requires mental preparation prior to every mission. As tasking increases, whether in actual combat or daily training, increased attention to human limits must be applied. Mental preparation includes managing stresses and distractions, allowing for total concentration on the mission. Habit patterns cannot be turned on and off at will, although in-flight distractions will interrupt them. The same skills and techniques developed during continuation training will be the ones used in combat. Avoid turning them into "rote" habit patterns—distractions then become killers. Professionalism and discipline are qualities common to all fighter pilots and the basis for the fighter pilot attitude. This ensures a proper blend of pride, desire, aggressiveness, and knowledge.

2.2.1.1. Situational Awareness. The cornerstone to formation success is SA. SA is the continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability to forecast, then execute tasks based on that perception. It is gained through assimilating information obtained through:

- On-board sensors.
- Visual cueing and perceptions.
- Flight members.
- Ground-controlled intercept (GCI)/airborne warning and control systems (AWACS).
- Support assets.

NOTE: The one most important aid in maintaining SA is a common understanding of the briefed plan. Overlaying current fight conditions to arrive at an overall picture of what is happening and what WILL happen defines SA.

2.2.1.2. Human Performance. Honest awareness of your capabilities as a human (mental and physical) and as a fighter pilot (proficiency and currency) in conjunction with thorough preflight preparation ensures:

- Use of superior knowledge versus superior skill.
- Faster reaction time to events with less probability of error.
- Reduced possibility of unanticipated events and uncertainty.

- Reduced need for in-flight planning.

NOTE: Analysis of these factors reduce the risk of distraction, channelized attention, task saturation, or procedural errors that will in the end increase attention requirements. In addition, building mission objectives based on current abilities and limitations prevents a mishap.

2.2.2. Physiological Considerations.

2.2.2.1. The High-G Environment. Modern fighter aircraft can exceed pilot tolerance for sustained high G's. This capability often allows pilots to apply more G's than their body can tolerate; and after a "short grace period," oxygen available to the brain is depleted and consciousness is lost. Pilots must anticipate the G, control the G-onset rate, and coordinate the G-straining maneuver. This requires mental discipline and practice to master. Failure to do so could spell disaster. G-induced loss of consciousness (GLOC) has two serious aspects. First, it is more dangerous than other pilot stresses because it is not possible for the pilot to accurately and reliably know how close they are to the GLOC threshold. Second, since amnesia (of the incident) is a characteristic of GLOC, the pilot may never recognize a loss of consciousness and may not be cognizant of any "close calls." The best solution to the GLOC problem is keyed to pilot awareness. The pilot has ultimate control over G-stress factors. Here are some factors to consider:

2.2.2.1.1. Flight Factors. High onset rates and long periods of sustained high-G seem to bring the pilot's body to the brink of exhaustion more quickly than at lower G-levels. High onset rates can bypass the normal stages of reduced vision resulting in near-instant unconsciousness.

2.2.2.1.2. Diet, Conditioning, and Rest. The result of good diet, proper physical conditioning, and adequate rest is a fighter pilot who is mentally and physically prepared to meet demanding mission tasks. The lack of respect for any one of these factors could be fatal in a high-G environment. There is also a synergistic effect when more than one of these factors are below standard. Be prepared, mentally and physically, for high-G stress. Proper physical conditioning involving anaerobic training (free weights, Nautilus, Universal Gym, etc.) and aerobic training (running, cycling, swimming, etc.) play an important role in improved G-tolerance. Proper mission planning begins with good physical and mental preparedness.

2.2.2.1.3. Currency, Anxiety, and Aggressiveness. G-tolerance is increased by adapting to repetitive exposure. Layoffs such as a long leave, DNIF, or even just coming out of a low-G flying phase require a build-up of G-tolerance. Anxiety in new situations or other pressures can mask objectivity in assessing tolerance. Aggressiveness, if not properly controlled, can lead to overconfidence and inattention to, or disregard for, the warning signs of fatigue and stress. Pilots need to be aware of these factors and be on guard for signs of G-stress limits. An individual's G-tolerance and warning signs can vary significantly from day-to-day. Fatigue, tunnel vision, or gray-out are critical warning signs that the pilot is already at his limit. Do not attempt to maneuver the aircraft up to these limits; there is no buffer or reliable safety margin. Expect G-tolerance to vary at different times even on the same flight, based on all the factors discussed above. When a pilot suspects effectiveness is being reduced, appropriate actions must be taken. In combat, it may mean separation if able; in training, it means a knock-it-off (KIO) and a less demanding alternate mission. Here are guidelines to follow:

- Identify high-G situations and maneuvers in the briefing for each mission and the proper techniques for avoiding GLOC.
- Tailor the mission accordingly if high-G sorties recently have not flown.
- Do not forget proper G-suit fit and straining maneuver techniques. By far the most important factor in improving G-tolerance is the performance of a good, well-timed, and coordinated G-straining maneuver.
- Perform a good G-awareness exercise.
- Anticipate the onset of G. Strain early.
- Make G-awareness part of SA in flight. Avoid "snatch pulls" to high-G. Make all G-inputs smooth, with controlled buildup, and within personal limits.
- Exercise strong flight lead control and seriously consider coming home early if any flight member feels fatigued.
- Although COMBAT EDGE-equipped aircraft decrease the effects of G-fatigue, do not become complacent. Always perform a correct G-straining maneuver.
- Do not sacrifice good training, but be sensitive to the dangers of GLOC through all engagements. Loss of consciousness is a serious problem, but it can be controlled. You and your approach to the entire problem are the keys to its solution. Take GLOC seriously; the consequences can be fatal. You will make the difference. For a comprehensive review of G-stress factors and GLOC, refer to AFP 11-404, *G-Awareness for Aircrew*.

2.2.2.2. Night Operations. With the introduction of new weapons and weapons systems, fighters are flying more at night than in the past. Thus, it is important for pilots to understand the physiological effects of night operations. Areas of primary concern affecting performance at night are circadian rhythm, sleep, and fatigue.

2.2.2.2.1. Circadian Rhythm. Circadian rhythm is defined as the "biological clock," meaning our physiological, psychological, and behavioral functions are subject to periodic daytime-dependent oscillations. Biological desynchronization and performance suffers when our circadian rhythm cycle is disrupted. The most common way to disrupt this cycle is through shift work. This can occur during the occasional night flight, one or two weeks of night flying, or a permanent shift in the flying schedule. Other ways to disrupt the cycle are to withdraw normal cues to daylight and darkness, and through transmeridian flight such as on a long deployment, causing jet lag. The ability to sustain performance is especially important to fighter pilots. Alertness is the major determinant of sustained performance and is influenced not only by man's inherent circadian rhythm, but also by the need for sleep.

2.2.2.2.2. Sleep. While partial sleep loss for any one night might impair performance, repeated partial sleep loss will have a definite impact on performance. Total sleep loss is the absence of sleep for at least 24 hours. This impairs the learning of new information and the recall of newly learned material. Susceptibility to disorientation may increase, scanning ability is reduced, and chart reading ability is affected. Most importantly, judgment and mood are impaired. Irregularity of work and rest over several days also result in decreased levels of performance. Combined with recent or cumulated sleep loss, irregular schedules can be especially fatiguing. Also, the length of the duty day for irregular schedules can further degrade performance. As with partial sleep loss, irregular schedules can increase susceptibility to the same factors resulting from total sleep loss.

2.2.2.2.3. Fatigue. Fatigue is tiredness, or exhaustion, from physical and/or mental exertion and is categorized as three types: (1) Acute fatigue is how you feel at the end of a physically/mentally demanding flight; (2) Cumulative fatigue is the tiredness you feel after extended periods of inadequate sleep; and (3) Circadian fatigue is the tiredness you feel from having your routine biological clock disrupted. The consequences of fatigue are degraded performance and less than peak efficiency. Research has determined that sleep loss and fatigue can lead to complacency, computational and navigational errors, and communication errors:

- Complacency is a sense of well being, often while unaware of potential danger.
- Mathematical and abstraction abilities crucial to accurate navigation, SA, and mission accomplishment are impaired.
- Communication errors occur by misinterpreting or not perceiving what is actually stated.

2.2.2.2.4. Compensation/Prevention. There are preventive measures to prepare for night operations and reduce the inherent risk: adjust sleep schedule, prepare specifically for the particular night mission, make good use of the simulator (operational flight trainer [OFT]/unit training device [UTD]). Cancel if not physiologically ready. It is the individual pilot's responsibility to determine preparedness for night operations.

2.2.3. Teamwork. Due to the complex and diverse nature of F-16 operations, preparation ensures the element works as a team with emphasis on effective communication as well as defined roles and responsibilities of lead and wingmen.

2.2.3.1. Task Management. Establishing a flexible task management plan allows for proper task prioritization, recognition of task saturation, and effective use of automated systems and all available resources in a dynamic environment.

2.2.3.2. Flight Leadership. Flight leaders have the general responsibility for planning and organizing the mission, leading the flight, delegating tasks within the flight, and ensuring mission accomplishment. They are in charge of the resources entrusted to them. They must know the capabilities and limitations of each flight member. Once airborne, the flight leader has the final responsibility and controlling authority for establishing the formations, maximizing the flight's effectiveness, and leading the flight successfully to and from the target.

2.2.3.3. Establishing Priorities. It is an acknowledged fact that during the heat of any mission, there are occasions when you cannot do everything in the time available. This requires assigning priorities (task prioritization). At the top of the list are things you have to do—do them first. Lower on the list are things you would like to do—do them later when they do not interfere with the have-to-do things. The list of have-to-do tasks should be established long before getting near an aircraft.

2.2.3.3.1. Critical Tasks. Those tasks that can never be ignored without catastrophic consequences. If any non-critical task becomes a higher priority, a terminate or KIO may be appropriate. As a minimum, immediately re-prioritize any critical task above the mis-prioritized task. Critical tasks fall in these general categories:

- Terrain avoidance (almost 100 percent probability of kill [Pk])..
- Flight path deconfliction (avoid other aircraft, training rule (TR) adherence).
- Maintain aircraft control (helps in avoiding the first two).
- Monitor, manage, and maintain sufficient fuel.
- Threat awareness/detection/defense (the lowest priority CRITICAL task).

2.2.3.3.2. Prioritizing Non-Critical Tasks. Lower priority tasks fall into two general categories: formation tasks and mission tasks. Formation tasks range from answering fuel checks on the radio to proper execution of tactical turns. Critical tasks can never be disregarded, but other tasks will require monitoring and management. For example, at 20,000 feet in close formation in the weather, formation tasks (staying in formation, radio awareness, instrument cross-check) should be prioritized above mission tasks (radar work, weapons management). Although mission success is usually measured by how well mission tasks are accomplished, keep overall mission success in perspective. Remember, *if you do not get yourself and your aircraft home, you have failed to accomplish the mission.* If formation tasks become secondary to mission tasks, as a general rule mission success will suffer. Letting nice-to-do things take priority over have-to-do things will jeopardize yourself and those around you. If the rare occasion comes up where aircraft malfunction/emergencies make it impossible for you to perform your top priority tasks, it may be time to eject (extreme).

2.2.3.3.3. Mis-prioritization. Mis-prioritization can have disastrous results. Many of the revisions in this volume are the result of accidents that occurred because of mis-prioritization. Search for situations that are most critical and mentally address what would happen in the cockpit: instrument cross-check, changing switches, checking six, checking mates' six, checking gas, or practicing a critical emergency. Stress basic SA. Fighter pilots are not born with it; SA must be developed and kept "current." Mentally engaging a MiG simply is not enough. "Look" at the fuel gauge and comprehend what it tells you: "JOKER FUEL" i.e., snap-shot, separate, expend flares (channelize the MiG driver's attention), run, where's lead?" Get the "big picture"—strive for "no surprises."

2.2.3.4. Wingman Responsibilities. Wingmen have critical responsibilities of helping the leader plan and organize the mission. They have visual lookout and radar responsibilities, perform back-up navigation tasks, and are essential to target destruction objectives. Wingmen engage as briefed or when directed by the leader and support when the leader engages. It is essential wingmen understand briefed responsibilities and execute the contract with discipline. Discipline is the most important quality a fighter pilot can possess and leads to success in the aerial arena. Discipline is executing self-control, maturity, and judgment in a high-stress, emotionally-charged environment. Teamwork is the foundation of the fighting element. If all flight members know and perform their respective duties, they work together as a team. Experience and realistic training leads to solid and professional air discipline.

2.2.3.5. Effective Communications. Communication ties all the work together. From the beginning of mission planning through the lessons learned in the debrief, communication is the basic determinant of both mission accomplishment and success. The mission commander must effectively translate the plan and objectives to each flight lead so assets can be directed to achieve the goals. The flight leads must communicate thoroughly during planning to produce the correct flight products for the mission. In the briefing they must address the flights execution plan and major contingencies that can be expected in flight and the planned reactions. Standards must be established to cover those contingencies that are not briefed. Briefings must be complete and understood so that contingencies can be executed in the air using concise radio communications. Visual signals must be understood and used correctly to be effective. Preparation to ensure effective in-flight communication includes:

- Know and adhere to accepted and standard terminology (squadron standards, Mission Planning Manual 3-1, Vol 1, and ATC).
- Brief anticipated communication flow.
- Zero tolerance for complacent, sloppy, or ambiguous radio calls (in flight and debriefing).
- Establish an appropriate assertion level, ensure two-way communication.
- Do not assume.
- State concerns and intentions and get an acknowledgment/decision.

2.3. Mission Flow. Whether a basic student upgrade sortie or a complex combat mission, successful accomplishment demands thorough preparation. This mission preparation consists of two phases, mission planning and mission briefing. Incomplete preparation in either area degrades mission accomplishment.

2.3.1. Preparation. The flight leader establishes priorities for mission planning and delegates them to flight members to ensure all planning considerations are addressed while precluding any duplication of effort. **Chapter 4**, Air-to-Air, and **Chapter 5**, Air-to-Surface, contain additional information specific to these roles. The depth of planning detail is dictated by the mission and flight experience level, but all necessary mission planning must be completed in time to conduct a concise, comprehensive briefing. The two main factors which determine the direction of mission preparation are the role of the F-16 for the particular mission (offensive counterair (OCA), interdiction, defensive counterair (DCA), etc.) and the overall mission objective (student training syllabus objectives, continuation training profile, visual bombing qualification, target destruction, etc.).

2.3.1.1. Planning Considerations. Additional factors, determined by the role and overall objective, which must be addressed during mission preparation include:

2.3.1.1.1. Higher headquarters (HHQ) guidance.

- Syllabus.
- MCI 11-F16, Volume 1 and Volume 3.
- Air tasking order (ATO).
- Rules of engagement (ROE).
- Special instructions (SPINS).

2.3.1.1.2. Flight composition and size.

- Experience level of flight members.
- Weapons delivery options.
- Aircraft configuration.
- Fuel tanks.
- Low-altitude navigation and targeting infrared for night (LANTIRN) pods.
- Weapons loads.
- Electronic countermeasure (ECM) pod.
- Air-to-air missiles.

2.3.1.1.3. Support forces.

- Controlling agencies.
- Escort, suppression of enemy air defense (SEAD), ECM support.

2.3.1.1.4. Communications.

2.3.1.1.5. Routing.

- Fuel considerations/refueling.
- Egress and safe passage procedures.

2.3.1.1.6. Contingencies.

2.3.1.1.6.1. Weather.

2.3.1.1.6.2. Fallout.

2.3.1.1.6.3. Threats.

- Cockpit indications.
- Capabilities.
- Numbers and locations.
- Electronic identification (EID) requirements.
- Visual identification (VID) requirements.

2.3.1.2. Mission Objectives.

2.3.1.2.1. Preparation. Preparation for any given mission is based on mission objectives tailored to the lowest common denominator. The objectives are performance standards to measure individual and team success during any mission, and should give the "big picture" of what is happening. A valid objective has three parts: performance, conditions, and standards.

2.3.1.2.1.1. Performance. This is what each pilot or the flight is required to do during the mission. It describes the action and is not vague. Use action verbs such as: demonstrate, employ, or practice.

2.3.1.2.1.2. Conditions. This is where it is happening, the environment. Examples include Line Abreast formation or outside the bandit's turn circle.

2.3.1.2.1.3. Standards. These state how well the performance must be done and are categorized by time limits, accuracy, and/or quality. Time-on-target (TOT) within ±30 seconds, hits within 10 meters, or ranging within ±500 feet are examples.

2.3.1.2.2. Objectives. Defining objectives also depends on contingencies and other planning considerations: weather, sun angles, day or night, the threat, or the air tasking order (ATO) are a few. Incorporating well-defined objectives based on the mission requirements and the particular mission's lowest common denominator (e.g., weather, wingman experience) pays benefits in terms of risk management.

2.3.1.3. Risk Management. Part of mission planning is assessing and managing the risks inherent in fighter operations with respect to individual limitations and vulnerabilities. Review the mission and clearly define what is to be accomplished. Then focus on critical phases throughout the flight, keep in mind many mishaps occur during takeoffs, en route, rejoins, and landings not just tactical operations in the military operating area (MOA). Attempt to assess all possible risks during these flight phases by building a mental picture of the sequence of events—look for the obvious risk factors, then ask yourself if something goes wrong how do I manage it? In addition, take a critical look at each of these areas:

- Pilot—proficiency/currency issues; physical and mental health, skill level, experience.
- Environment—weather, time-of-day (TOD), terrain, altitude, G's, temperature.
- Aircraft—configuration limitations, cockpit setup, distractions-eye magnets.
- Supervision–personality conflicts, discipline, supervisory and peer pressures.

2.3.2. Mission Briefing. The briefing sets the tone for the entire mission. Establish goals and have a plan to achieve them. Write the mission objectives on the board and establish a standard which measures successful performance. Standard briefing items include start, taxi, takeoff, recovery, and relevant special subjects should be covered in an efficient manner. As computerized briefing outlines become available, squadron and MAJCOM standards can be integrated into automatic presentations. Elements of the mission, which are standard, should be briefed as "standard." Spend most of the time describing the "what" and "how to" of the mission. If adversaries, friendly players, intelligence (Intel), or other mission support personnel are present, brief them first on only pertinent information and the mission. GCI/AWACS controllers, however, should receive the entire tactical briefing and must fully understand the game plan to include ROE review, identification procedures, and the communications plan. Alternate missions should be less complex than the original mission but also have specific objectives. The flight lead must control the brief and be dynamic, credible, and enthusiastic. The flight lead motivates and challenges the flight to perform to planned expectations, asking questions to involve flight members and determine briefing effectiveness.

2.3.3. Debriefing. The objective of the debrief is to determine if the desired mission objectives were achieved, identify lessons learned, and define aspects of training needing improvement. The end result should be all participants gaining solid direction after the debrief on how to do it better next time. An effective debrief includes three main areas: preparation, reconstruction, and analysis.

2.3.3.1. Preparation. This step will make the difference between an effective and efficient debrief and a 6-hour mess. Flight leads should have a specific mission debriefing guide aligned with the mission briefing guide; this will ensure a logical structure and flow. All participants should know (from the briefing) what will be required from the flight lead during the debrief, and sufficient time between arriving in the debrief area and starting the actual debrief should be allowed to gather that information (normally 20 to 30 minutes).

2.3.3.2. Reconstruction. The "what happened" during the mission occupies most of the debriefing. Correct preparation by all participants will greatly streamline this phase. For telephonic debriefing, use of faxes will greatly help during flight reconstruction. At the beginning of the debrief, brief the ROE, so all participants know when to interrupt, provide information, and make corrections. During reconstruction, assign roles to each participant to focus attention and keep them involved. Typical assignments are:

- Objectives/execution monitor (Number 1).
- Training rules monitor (Number 2).
- Communications monitor (Number 3).
- Weapons validation monitor (Number 4).

NOTE: Flight leads must be aware of all participants debriefing limitations. These may range from tight turn times to the next days sortie; follow-on simulators or academic training; or personal commitments. Tailor the reconstruction so that essential errors are identified while considering these limitations. Sometimes debriefs will be required to be slipped to the next day. Here are ten reconstruction tips to consider:

- Preflight the room (tape players and pens).
- Annotate Bullseye on the board with 5 NM tics down fight axis.
- Double check the initial picture (have a correct start point).
- Do not draw inner group pictures until it is important to know it.
- Show spike status with color codes and direction.
- Keep arrows synched (equal numbers for all players/groups) and in scale.

- Mark all shots, include from and to whom, type, and outcome.
- Show countermeasure (CM) use when expended.
- Tag all groups with altitude and annotate changes.
- Put notes on board for discussion items during analysis (probably the most important).

2.3.3.3. Analysis. This phase brings out the actual "what to do better or different" focus from the flight. It is essential to derive accurate lessons learned; not simply the execution errors that occur in every sortie. Primary consideration should be toward gaining insight into how the pilot has performed versus the mission objectives. Get the small items out of the way first (i.e., debrief the motherhood). Discuss significant departures from the briefed flow or established procedures without belaboring the items. Review the mission objectives and provide a general impression of mission success.

2.3.3.4. Final Summary. Choose only the significant events that impact the objectives of the ride. Use the notes on the board identified during reconstruction. Identify execution errors, and draw from them lessons learned, if appropriate. The final summary includes an assessment of strong and weak points and the required corrections for next time.

CHAPTER 3

FORMATION

3.1. Basic Formation. Formation can be defined as two or more aircraft working with understood roles and under one lead's control. Formation integrity and unity of effort, can only be maintained when the leader has complete knowledge and control of the actions of each flight member. The flight leader will brief the formations to be flown and formation responsibilities. Wingmen will maintain assigned formation position until change is ordered or approved by the flight lead.

3.2. Communication. The primary means of communication in the Viper is through radio (ultrahigh frequency [UHF], very high frequency [VHF], data) and visual signals. Flight discipline can be determined from communications, whether by radio or visual signals. Communication, to be effective, must be received and understood by every flight member. A key to clear, concise, and correct communications is the use of AFTTP 3-1, Volume 1, Brevity Words.

3.2.1. Radio Discipline. Another key to effective communications is discipline. Radio discipline requires not only clarity and brevity in the message, but limiting unnecessary transmissions as well. Never give up a chance to be quiet on the radios, BUT to communicate essential information to the rest of the flight (world) is required for mission success. This is a fine line that is debriefed after every mission.

3.2.2. Radio Transmissions. The first part of any radio call should always be the "call sign." This alerts the listener that a message is coming (attention step) and specifies to whom it is directed. Failure to use the correct call sign, reliance on voice recognition, or simply not using full call sign due to flight size, builds and reinforces poor habit patterns which are not easily transferred into large packages or wartime employment. If assigned a cumbersome, or difficult to use call sign, request a new assignment during preflight planning.

3.2.2.1. Acknowledgments. Immediate response acknowledgments will only include flight number (i.e., "two"). For all self-initiated calls or responses that are delayed, full call sign must be used. EXAMPLE: "VIPER 21, GROUP, BULLSEYE 210º, 25 MILES, 30,000 FEET, BOGEY." Acknowledgment: "TWO, SAME." Delayed acknowledgment: "VIPER 22, SAME." Use visual signals whenever practical. If responding to a change in formation or flight maneuvering, actual maneuvering by the affected aircraft/element will suffice for acknowledgment, if visible to the directive fighter. Only standard signals should be used unless otherwise briefed by the flight lead.

3.2.2.2. Standards. Standard in-flight radio terminology is made up of three parts: "Call sign, directive transmission, descriptive transmission." It is important to structure calls in this format so that flight members know what to expect and make sure the most important part of the transmission (the who and action desired) is received first. EXAMPLE: "VIPER 21, BREAK LEFT!!!, BOGEY, 6 O'CLOCK, 1 MILE." Normally defensive-type directive calls need both volume and tone inflection to be most effective.

3.3. Ground Operations. Prior to step, the flight lead should confirm configuration to ensure the aircraft/pilot combinations are optimized. Fuel tanks, model, weapons configurations, and takeoff type, are some of the most obvious factors to be considered. Ensure takeoff and landing data (TOLD) is available for each expected configuration and takeoff type. Each pilot should make a quick study of the aircraft historical data for any system peculiarities. Before takeoff, a thorough check of all aircraft systems should be completed IAW the Dash 1 and Dash 34 checklists, and the flight lead informed of any problems. Initial check-ins should confirm operation of all radios and radio modes (HAVE QUICK, Secure) expected to be used in flight. Sufficient time should be allowed to have radios re-keyed after check-in prior to taxi.

3.4. Takeoff. The leader will direct the appropriate runway lineup based on winds and runway width.

3.4.1. Lineup. The correct lineup will allow visual signals to be passed and simultaneous runup without putting any aircraft in aircraft exhaust. Care should be taken during lineup to maintain taxi spacing and ensure aircraft do not come in contact.

3.4.1.1. Two-Ship Lineup. Wingmen should line up ensuring wingtip clearance (runway width permitting) and just slightly forward of the normal in-flight reference (line up the main landing gear wheels). If runway width is not a factor, wingmen should line up with 3 to 5 feet wingtip spacing.

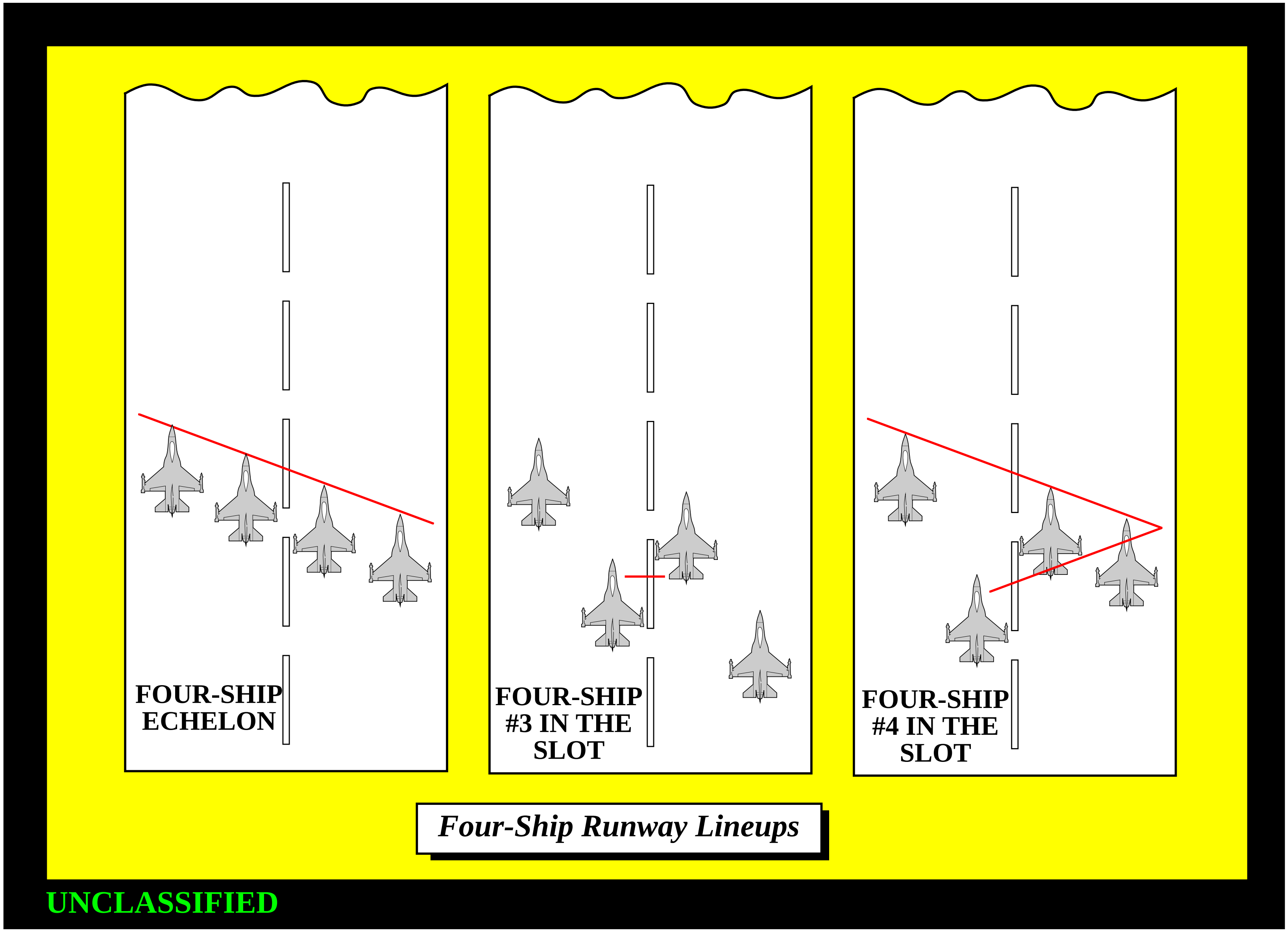
3.4.1.2. Four-Ship Lineup. **Figure 3.1.**, Four-Ship Runway Lineup, depicts the three options that are normally used.

3.4.1.2.1. Four-Ship Echelon Lineup. Number One should take the downwind side of the runway with Number Two in the normal 3- to 5-foot wingtip spacing. Numbers Three and Four should align helmets of preceding flight members.

3.4.1.2.2. Three-in-the-Slot. Number One should take the downwind side of the runway with number Two putting the missile rail (nearest lead) on the centerline. Number Three should split the distance between Number One and Two and pull forward until lining up Number Two's afterburner (AB). Number Four should line up on Number Three with the same spacing that Number One and Number Two have.

3.4.1.2.3. Four-in-the-Slot. Similar to three in the slot, except Number Three pulls forward to normal echelon position on Number Two and Number Four pulls forward so that Number Three’s helmet is visible in front of Number Two's tail (over the spine).

Figure 3.1. Four-Ship Runway Lineup.



3.4.2. Formation Takeoff Execution. Following takeoff clearance, a visual channel change to departure and a "run-em-up" signal (spinning vertical index finger) will be passed from the flight lead and copied between the flight. After all aircraft have indicated "ready," the flight lead will check-in and signal for takeoff. During daytime, the flight lead will signal for brake release with a single head nod. The wingman should simultaneously select MIL or MAX as briefed while maintaining wingtip clearance. The flight lead should select a power setting below that of the wingman (not less than the computed formation takeoff fan turbine inlet temperature [FTIT]). This is normally one-half to one knob-width below the briefed takeoff setting. Wingman should reduce power slightly to maintain position. The best technique is to concentrate on flying formation after brake release, then to rotate with lead as the nose strut extends. When safely airborne, the leader will pass a gear up (reverse head-nod) and AB out signal (forward to aft fist movement), if appropriate. If the visual gear signal is missed, raise the gear when the lead's gear starts to move. Confirm gear is up and locked prior to exceeding 300 knots. Move smoothly into Fingertip while checking lead's aircraft from front to back to detect open panels, open gear doors, fuel or hydraulic leaks, etc.

3.4.3. Wingman Actions. The wingman will maintain wingtip clearance throughout the takeoff roll. Ask lead for a power adjustment if unable to maintain position (Example: "SPAWN 1, PUSH IT UP/PULL IT BACK"). The flight lead will then select the maximum briefed power setting or the minimum FTIT. If still overrunning the leader ensure wingtip clearance and make a separate takeoff. If still falling back, recheck engine gauges and takeoff in trail with the flight lead. If either member of the element must abort, the other member should continue the takeoff. In either case, directional control (staying on your side of the runway) is essential to prevent collision.

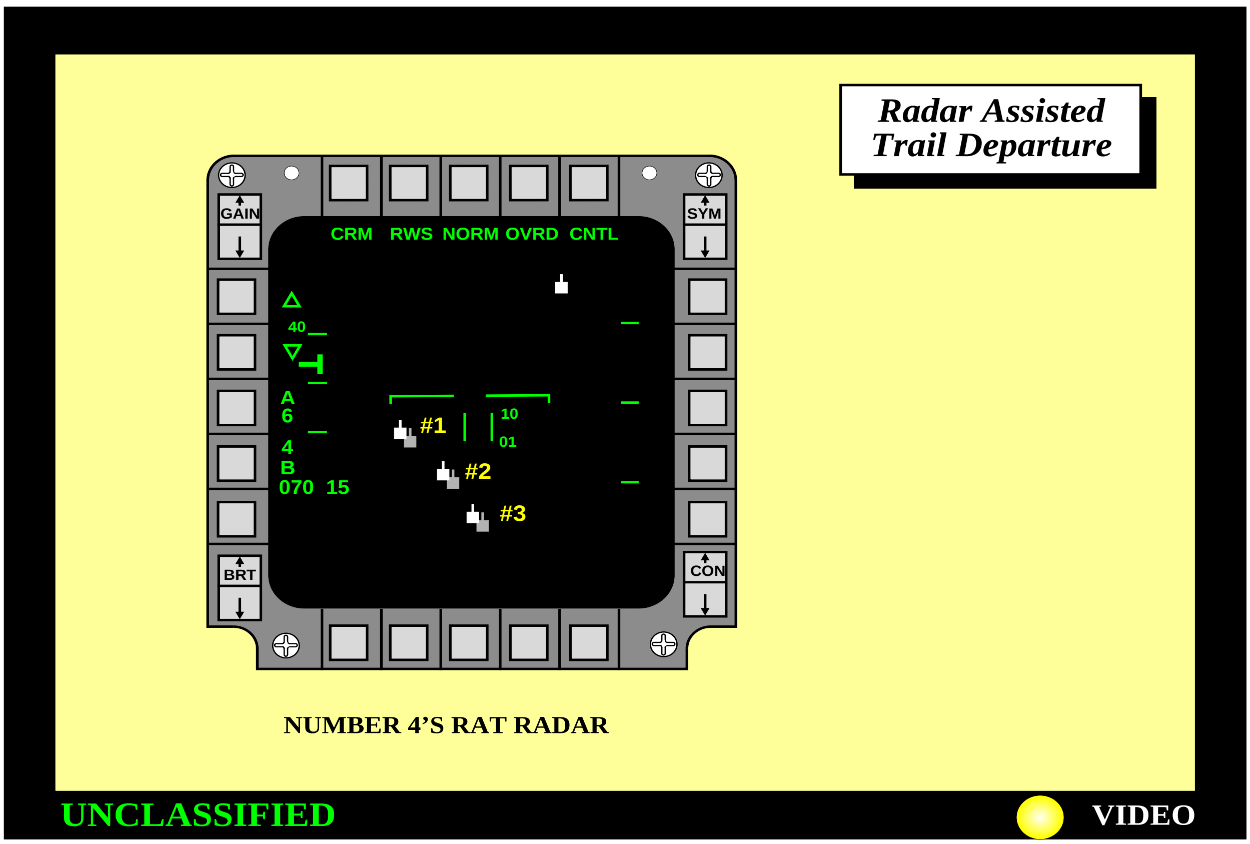
3.5. Trail Departures. A trail departure is normally used to get a flight of two or more airborne when conditions will not permit a formation takeoff. Wet runways, crosswind limits, weapons loads, configuration differences, and low ceilings or poor visibility are normally deciding factors. Visual departure and rejoin are preferred to trail departures in IMC due to increased air traffic control (ATC) coordination caused by non-standard formations. Also, the required departure altitudes combined with high terrain and weather will require special consideration by the flight lead. Altitude deconfliction between all flight members must be available in the event of radar failure or no radar contact.

3.5.1. Preparation and Execution. Prior to takeoff, review the departure and set up navigation aids appropriately. All flight members must acknowledge the clearance, and prepare for non-standard or unpublished restrictions.

3.5.1.1. Visual Departure and Rejoin. The primary consideration during this maneuver is to maintain sight with the rest of the flight while rejoining to the briefed formation. Unless otherwise briefed, rejoins after departure will be to close formation (**paragraph 3.6.1**). The radar should be utilized to clear for other aircraft, but may be used to aid in maintaining visual and controlling closure. Normal radar lock technique is to use boresight to accurately select the correct flight member to rejoin on. Standard rejoin techniques (**paragraph 3.6.7**) should be used, while complying with any departure restrictions. The flight lead must adhere to briefed airspeeds and power settings until joined to reduce overshoot potential and allow for expeditious rejoins. If Number Four rejoins on Number Three prior to rejoin with the front element, Number Four will rejoin IAW Number Two's contract (left/inside). A crossunder may then be required prior to rejoin with the front element and will be directed by Number Three. In the event of an overshoot by any flight member, primary consideration must be to regain nose-tail clearance while deconflicting flight path's. In the event of an overshoot by Number Two, Number Three must utilize extra care.

3.5.1.2. Radar-Assisted Trail (RAT) Departure. In the event a trail departure is required to be flown and an immediate rejoin is not feasible (weather, ATC, departure restrictions) a RAT will be flown. Critical tasks (instrument flying and departure adherence) must be accomplished prior to other taskings (radar work and radio calls) during this maneuver. All flight members must have an in-depth knowledge and ***adher to*** the departure and formation contracts for airspeed, bank angles, and power settings.(See **Figure 3.2.**, Radar- Assisted Trail Departure.)

Figure 3.2. Radar Assisted Trail Departure.



3.5.1.2.1. Standard Radar Setup: This setup provides for multi-ship departures and allows trailers to sort the other flight members. Air combat mode (ACM) is not used because scan volumes are insufficient and locks to the wrong flight member are likely. ACM is only useful when able to visually verify and have a lock on the correct aircraft prior to weather penetration.

- Range While Search (RWS) or Normal Air Mode (NAM).
- Scan: 10 NM scope, ±60 degrees sweep, elevation slightly above detent.
- Target history 2+, channel as briefed.

3.5.1.3. Use of the Head-Up Display (HUD). Use caution during all flight phases in order to avoid the tendency to channelize attention in the HUD. Do not maintain radar trail through sole use of the HUD, and be particularly cautious during the subsequent rejoin. Always backup the cross-check through the use of the head-down displays (HDD).

3.5.1.4. Takeoff/Transition to Instruments. During the takeoff, maintain aircraft control by making a timely transition to instruments as outside visual cues deteriorate. The overriding priority must be flying the aircraft, NOT operating the radar. Get the aircraft safely airborne, gear retracted, and establish a safe climb at departure airspeed. Reset the power, as briefed, to ensure the flight profile accurately matches the rest of the flight. Do not transition from the basic instrument cross-check until these tasks are completed and able to precisely fly the departure.

3.5.1.5. Climb Out. During the climb out, maintain the briefed power setting (FTIT: PW-850º, GE-750º) and airspeed. Listen to the radio for instructions and information. Accurate flying of the departure, not the radar, ensures clearance from terrain and the rest of the flight. Unless restricted by a standard instrument departure (SID) or controller instructions, begin all climbs at the same time as the leader (usually when lead acknowledges the altitude change).

3.5.1.5.1. Radio Calls. Lead should call passing every 5,000 feet mean sea level (MSL) increment, and any turns off the briefed departure until all flight members have reported "TIED." Wingmen should report "TIED" only when 100 percent sure they have gained radar contact on the correct flight member and can maintain radar SA until "VISUAL."

3.5.1.5.2. Maintaining Formation. For turns using 30 degrees of bank, allow the preceding aircraft to drift 5 degrees from the center of the multi-function display (MFD) for each mile of separation or delay approximately 20 seconds from the "TURNING" call without radar contact. For example, to maintain a 2 NM trail position, allow the preceding aircraft to drift 10 degrees before initiating the turn; to maintain a 3 NM trail position, allow the aircraft to drift 15 degrees before starting the turn (20 seconds delay is a good tradeoff when not tied).

3.5.1.5.3. Adjusting Formation. If spacing is greater than desired, initiate the turn prior to the standard lead point to establish cutoff and decrease separation. One technique is to keep the target at 0 degrees azimuth during a turn. This "pure pursuit" technique establishes an easily controllable amount of cutoff. As the desired separation is attained, roll out of some bank and let the aircraft drift to the appropriate azimuth. If spacing is less than briefed, allow the preceding aircraft to drift beyond the normal lead point before initiating the turn and separation will increase. As a technique, letting the target drift no more than 10 degrees colder than the azimuth required to maintain spacing works well. At the desired separation, increase the bank angle slightly to bring the target to the correct azimuth.

3.5.1.6. Using the Radar. After the requirements of **paragraph 3.5.1.4** have been met, start bringing the radar into the cross-check. The preceding flight member should be displayed as histories approximately 2 NM in front of you (10 percent scope). If not, check the search elevation and confirm the correct radar setup. Do not sacrifice basic instrument execution to accomplish radar work! More than one wingman has been without radar contact, 2 NM behind and below lead, due to incorrect antenna elevation positioning. A mistake of this nature can be disastrous if combined with weak instrument flying. Expect each set of histories to be superimposed or extremely close together when other flight members are at or near the same airspeed. If there are numerous contacts, concentrate on those which are at a range and azimuth on the scope consistent with the departure ground track. Again, do not allow your attention to be channelized on the radar if you are having trouble gaining contact. At the first indication of task saturation or disorientation, immediately concentrate on flying instruments. Flying the aircraft is always the first priority. (See **Figure 3.2.,** Radar Assisted Trail Departure.)

3.5.1.6.1. Contact Established. The first decision is whether to lock the previous aircraft or to fly a no-lock trail departure. A no-lock departure allows you to clear your flight path and maintain better overall SA, but it is normally easier to maintain precise position and "TIED" with a lock. As Number Three or Number Four, selection of situation awareness mode on the nearest aircraft will put the radar in single target track (STT). Ensure the cursor is precisely placed over the correct aircraft prior to commanding lock. ACM mode to gain a lock in the weather is not desired. If, for example, you are Number Three and do not realize that the ACM lock is on lead instead of Number Two, the result could be a mid-air collision since both you and Number Two are trying to fly the same position behind lead. No matter the method, all locks should be verified by ensuring the target is at the correct range, azimuth and altitude, and is flying the proper ground track at the briefed airspeed. If there is a doubt, immediately return to a search mode to regain and ensure SA. If radar SA can be maintained call "TIED."

3.5.1.6.2. After Tied. Fly radar trail by thorough reference of the radar display and the HUD. While all data is available on the radar display, azimuth and range information is not as precise as that shown in the HUD. With a radar lock, reference the target designator (TD) box (or target locator line [TLL]) for azimuth, and the target range and closure rate displays for separation. While a printout of the target's elevation is not available in the HUD, compare the TD box (or TLL) elevation in HUD to get a fairly good estimate. Use of horizontal situation display (HSD) and data link systems can greatly increase SA at this point if operating correctly.

3.5.1.6.3. Visual Transition. After regaining visual meteorological conditions (VMC) and maintaining visual with the preceding aircraft call "VISUAL." After all flight members have called visual, expect the flight lead to direct a rejoin to the briefed en route formation.

3.5.2. Prioritization. Constantly reevaluate current conditions during the departure. Remember, the bottom line is to maintain aircraft control and fly instruments. Watch out for task saturation, channelized attention, and disorientation. Radar work takes a back seat when prioritizing tasks. A detailed discussion of task management is in **paragraph 2.2.3.1.** Successful trail departures have been flown for decades without the use of a radar.

CHAPTER 3-8

3.6. Formations and References. A complete understanding of formation references and limits is essential to flying superior formation. Wingmen should be completely familiar with all the formations referenced in this chapter.

3.6.1. Fingertip (Close) Formation. Fingertip is flown in a position that aligns the front portion of the wingtip missile launcher rail (or forward missile fins) with a point halfway between the environmental control system (ECS) duct and the leading edge of the intake fairing. Fly to align the trailing edges of the exhaust nozzle. Turns by the flight lead do not adjust the formation "picture" (**Figure 3.3.,** Fingertip Position References).

Figure 3.3. Fingertip Position References.

3.6.2. Route Formation. Route formation is flown as a modified Fingertip formation with up to 500 feet between aircraft. When turned away from, the wingman will stack level with the leader. When turned into, the wingman will only stack down enough to keep lead in sight and avoid the maneuvering aircraft.

3.6.3. Echelon. Echelon formation can be flown in either Route or Fingertip. If in Fingertip, turns will only be made away from the Echelon. If a turn into the Echelon is unavoidable, in Fingertip, use minimum bank. If in Route formation, and a turn is made into the Echelon, each aircraft will only stack down enough to keep the rest of the formation in sight and avoid their maneuvering plane. Lead should avoid excessive bank angles. On turns away from the Echelon, all aircraft will maintain the same horizontal plane and the same formation spacing.

3.6.4. Trail Formations.

3.6.4.1. Close Trail. This position is defined as one to two ship-lengths behind the lead aircraft and below the jet wash.

3.6.4.2. Trail. This formation is flown in a cone 30 to 60 degrees aft of lead at a range briefed by the flight lead to accomplish specific requirements. Avoid flying at lead's high 6 o'clock and use caution not to lose sight of lead under the nose.

3.6.4.3. Chase Formation. Chase formation is used during high tasking situations to monitor and assist the lead aircraft in accomplishing required checks. Care must be taken by the chase aircraft to not be a flight conflict to the lead aircraft. The lead aircraft may not provide any visual support to the chase. The chase aircraft is responsible for all flightpath deconfliction, while performing the monitor duties above.

3.6.4.3.1. Safety Chase. Safety chase is flown in a maneuvering cone 30-60 degrees aft of the lead aircraft, from 300-1000 feet back. Provide assistance as directed. As a minimum provide altitude awareness calls, refer to the checklist if the situation dictates, and advise the lead aircraft of any unusual events (smoke, visible leaks, lack of gear prior to landing). Do not close inside 300 feet unless directed by the lead aircraft for weather penetration or visual checks. Match the lead aircraft’s configuration as soon as changes are apparent.

3.6.4.3.2. Evaluation Chase. Instructors may fly chase formation from a much closer range than during safety chase. Evaluation Chase uses the same maneuvering cone, but allows flight all the way into fingertip position. Normally, do not fly inside that range required to effectively monitor lead aircraft performance (about two ship widths). Increased care must be used so that mid-air collision potential is minimized. A normal technique is to beat the lead aircraft to any configuration change (lowering the gear, or opening the speedbrakes) to maintain a power or drag advantage.

3.6.5. Show Formations.

3.6.5.1. Diamond: Wingmen fly normal Fingertip formation. The slot pilot flies a close trail position maintaining nose-tail clearance. Current restrictions may not allow this formation.

3.6.5.2. Missing Man: Normal four-ship Fingertip formation. On command from the leader, the Number Three aircraft pulls up and out of the formation. The Number Four aircraft holds position, maintaining relative spacing between the leader.

3.6.6. Crossunders. A crossunder is either directed on the radio or by a slight wing dip toward the wing you are directing the affected aircraft/element to go to.

3.6.6.1. Two-ship. Number Two drops below and behind Number One and moves to the directed wing. No part of Number Two's aircraft passes below the lead's aircraft. Wingman should strive to pass less than one-half ship-length behind the lead. Number Two should then assume the formation departed on the new wing.

3.6.6.2. Multi-ship. When the Number Two aircraft is required to crossunder in a flight of three or more, number three (or the element) will move out to allow Number Two sufficient spacing to move into position. Number Two performs a normal crossunder. Number Three will then move in on Number Two's wing. When an element is required to crossunder, the element will drop below and behind the lead (element) maintaining nose-tail and vertical clearance, cross to the opposite side, then move up into position. Number Four performs a crossunder on Number Three after the flight has achieved nose-tail separation.

3.6.7. Rejoins. Any rejoin requires an accurate appraisal of position and closure. The low drag nature of the F-16 and relative ineffectiveness of small throttle changes in slowing down requires some anticipation for power reduction. The speed brakes are effective in reducing overtake at normal flying airspeeds (300 knots and above).

3.6.7.1. Turning Rejoins. In this maneuver the lead will maintain 350 knots and 30 to 45 degrees of bank. Flight members maintain approximately 400 knots. Number Two rejoins to Fingertip on the inside wing and Numbers Three and Four join to the outside. If the rejoin subsequently becomes straight-ahead (lead rolls out) continue to the wing originally maneuvering toward (do not reset to the straight-ahead contract).

3.6.7.1.1. Visual Reference. A visual reference for a normal turning rejoin line is to obscure the far wingtip with the top of the vertical tail; you may be forward (slower) or aft (faster) of this line depending on relative airspeeds (**Figure 3.4.**, Turning Rejoin Sight Picture). Keeping the lead aircraft slightly above the horizon and comfortably visible will avoid an end-game vector into lead, while allowing for a controllable overshoot.

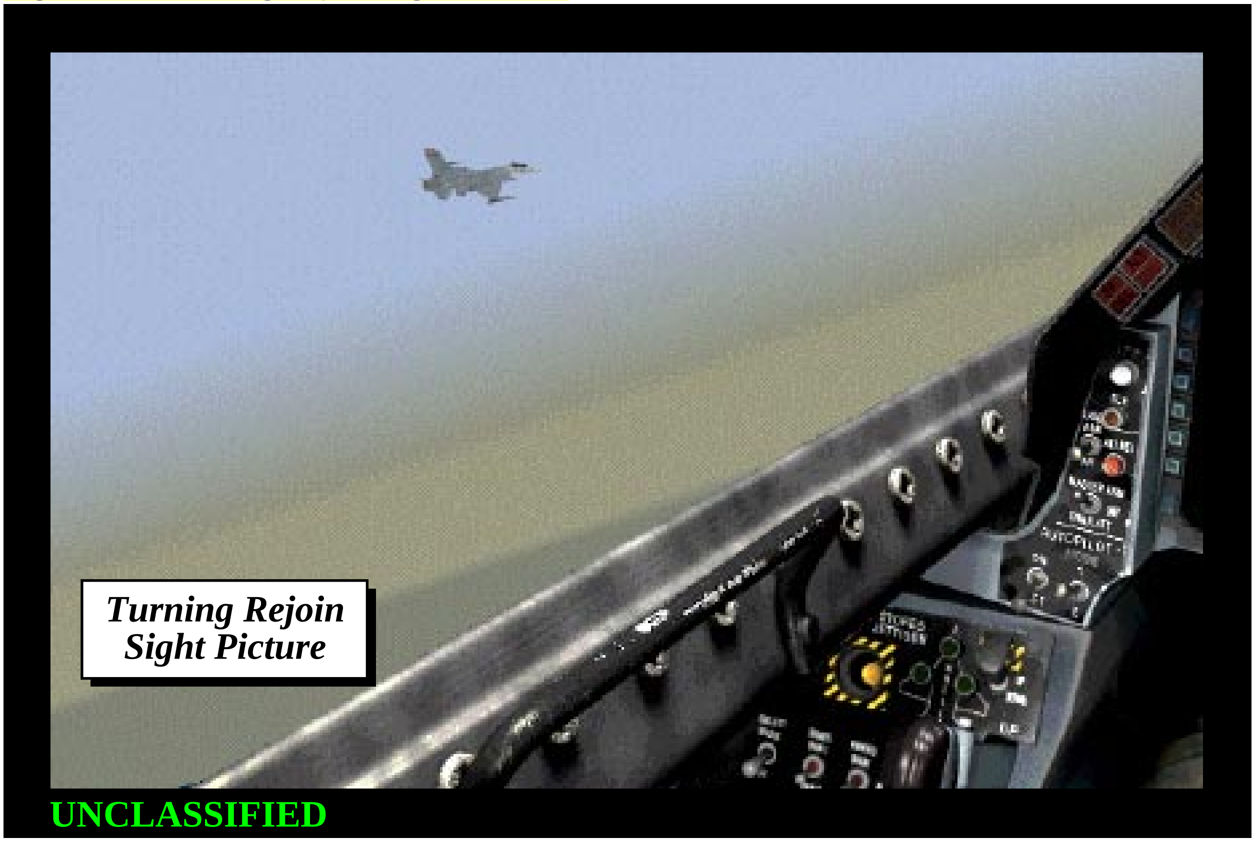
3.6.7.1.2. Radar Lock-On. A radar lock-on may be used during the rejoin to provide range and overtake information.

3.6.7.1.3. Position. If you are Number Three or Number Four, ensure that you are locked to the leader and stay visual with Number Two.

3.6.7.1.4. Speed Reduction. As separation decreases to approximately 3,000 feet, reduce power smoothly to control overtake. At approximately 1,500 feet, overtake should be about 50 knots. Consider using the speed brakes if overtake is excessive. Stabilize momentarily in Route and then smoothly move into the Fingertip position. If overtake is excessive approaching the extended Fingertip position, initiate a controlled overshoot early enough to allow nose-tail separation.

3.6.7.2. Straight-Ahead Rejoin. Lead should maintain 350 knots unless otherwise briefed. Number Two rejoins to the left wing, Numbers Three and Number Four to the right. Wingmen should strive for a radar lock due to the reduced closure cues at 0 degrees aspect. Flight members should maintain approximately 75 to 100 knots of closure until inside 3,000 feet. At this point make a slight turn to arrive at about 200 feet lateral spacing from lead while reducing closure to less than 50 knots by 1,500 feet. Stabilize in Route and then move in to Fingertip.

Figure 3.4. Turning Rejoin Sight Picture.



3.6.7.3. Overshoots. If the overtake is excessive and cannot be controlled with power and speed brakes, initiate an overshoot:

3.6.7.3.1. Turning. If turning, reduce bank and slide to the outside of the turn. Ensure nose-tail separation and pass behind and below the flight lead. Once line of sight (LOS) begins moving forward, perform a normal crossunder to the inside wing. Stabilize in Route and then move in to Fingertip.

3.6.7.3.2. Straight-Ahead. If straight-ahead, check away from the lead and stay slightly low on the formation. Keep lead in sight, stabilize, move back to Route and then into Fingertip.

3.6.8. Lead Changes. Lead changes require an unmistakable transfer of responsibilities from one flight member to another. Lead changes may be initiated and acknowledged with either a radio call or visual signal. Visual contact with the new lead is required prior to initiating a lead change. The flight member assumes lead will be no further aft than the normal Route/Fingertip position prior to initiating or acknowledging the lead change. The lead change is effective upon acknowledgment. All flight members must continue to ensure aircraft separation as positions are changed. The new leader must continue to monitor the new wingman's position until the leader is established in front with the wingman looking at lead. If the radio is used for the lead changes, use call signs and be specific. The wingman assuming the lead will so state in his acknowledgment. Lead changes using visual signals are preferred since it guarantees that the flight members are looking at each other. Whether done visually or using radio calls, all flight members must monitor aircraft separation until the new positions are established.

3.6.9. Operations Checks. The flight leader will initiate operations checks. This is the time to confirm proper fuel state, fuel transfer, engine operation, and operation of life support equipment. It is each pilot's responsibility to continually check these items without prompting by the flight leader.

3.6.10. Weather. Formation in the weather may require some adjustment in formation procedures. The aircraft is very responsive to pilot inputs; therefore, a smooth, steady hand and a light grip are essential.

3.6.10.1. Flight leaders. When flying formation in instrument meteorological conditions (IMC), or transitioning from VMC to IMC, monitor attitude and altitude so as not to exceed 30 degrees of bank or enter an excessive descent rate.

3.6.10.2. Wingmen. When flying close in turbulent conditions, do not attempt to rapidly counteract every gust with control inputs. Remember, the leader is flying in the same patch of air, and both aircraft will react the same way to rough air. Use smooth corrections and avoid rapid erratic control inputs. Lost wingman procedures should be used if you lose sufficient visual formation reference.

3.6.11. Leaving Formation. It is the duty of the wingman to leave the formation:

- When directed to do so.
- When visual is lost.
- When unable to join up or to stay in formation without crossing over, under, or in front of the aircraft ahead.
- At any time you feel that your presence in the formation constitutes a hazard.
- When you leave formation, clear your flight path in the direction of your turn and notify lead. If you have lost sight, comply with the appropriate lost wingman procedures.
- Rejoin only when directed to do so by the flight lead.

3.6.12. Lost Wingman Procedures. Refer to MCI 11-F16V3, *Pilot Operational Procedures*. Rejoin only when directed to do so by the flight lead.

3.6.13. NORDO/Emergencies. Comply with briefed procedures. The flight lead will usually brief NORDO rendezvous point and escort requirements during the mission briefing.

3.6.14. Formation Landing.

3.6.14.1. Lead Procedures. The flight lead must fly the best approach and landing while giving the wingman consideration for differences in configuration:

- Establish an approach speed consistent with the heavier aircraft.
- Position the wingman on the upwind side if the crosswind component exceeds 5 knots.
- Plan to land near the center of your half of the runway to ensure enough runway is available for the wingman.

- Ensure touchdown of the heavier aircraft is no slower than 13 degrees AOA.
- Do not touchdown long and fast.

3.6.14.2. Wing Procedures. The wingman must fly precise formation and match leads jet configuration and airspeed. During the transition to landing:

- Maintain a minimum of 10 feet lateral wingtip spacing and stack level with the lead aircraft inside the final approach fix (FAF) and visual with the runway, or as briefed by the flight lead when VMC and configured on final.
- Cross-check the runway and ensure sufficient runway is available.
- Go around or execute a missed approach if sufficient runway or aircraft clearance is not available.

3.6.14.3. Roll-out Procedures:

- Prior to aerobraking, the leader should hold landing attitude until nose-tail separation is assured.
- The wingman should smoothly aerobrake to 11 to 13 degrees AOA, avoiding abrupt aft stick inputs.
- Each pilot will maintain their landing side of the runway until slowed to normal taxi speed.
- After assuring clearance, move to the turnoff/cold side of the runway. Wingmen may clear the leader to the cold side after their aircraft is under control.
- If the wingman overruns the leader, accept the overrun, maintain the appropriate side of the runway, and do not attempt to reposition behind the leader. The most important consideration is wingtip clearance. Although a verbal lead change is desired (Example: “SPAWN 2, YOU HAVE THE LEAD” “SPAWN 2, HAS THE LEAD”) it is not required.

3.7. Tactical Formation. Varying factors of the tactical arena (weather, visibility, background, terrain, threat, etc.) will determine the position and responsibilities for the individual flight members. Central to all maneuvering must be a capability to communicate intent, role, and threat information. Definitions of pilot responsibilities and emphasis on air discipline will help ensure success in a restricted communications environment. The formations described in this chapter are applicable for both air-to-air (A/A) and air-to-surface (A/S) operations. The guidelines given have proven to be the most universally applicable. As the tactical situation changes, the numbers given here may change. For a more detailed discussion on how and why various factors effect formation decisions refer to Mission Planning Manual 3-1, Volume 1 and Advanced Employment Manual 3-1, Volume 5. Remember, flying a given formation is not an end in itself; it facilitates proper task prioritization, lookout, and offensive and defensive considerations. If you cannot perform your responsibility in a formation listed, get into one which does permit you to carry out your formation responsibilities. The flight briefing should cover, as much as possible, any changes that may be necessary.

3.7.1. Mutual Support. A vital subset of SA is mutual support. Mutual support is a contract within a flight of two or more aircraft that supports the flight's mission objectives. An effective mutual support contract will enable a flight to maintain the offensive while enhancing its survival in a hostile environment. Mutual support in the modern combat arena is more directly related to SA than ever before. It demands position awareness of other flight members and the threat as well as an understanding of the flight's and the threat's weapons capability. Flight leads must carefully assess the experience and proficiency level of their flight members when developing the flight's mutual support contract. A sound mutual support contract should provide for:

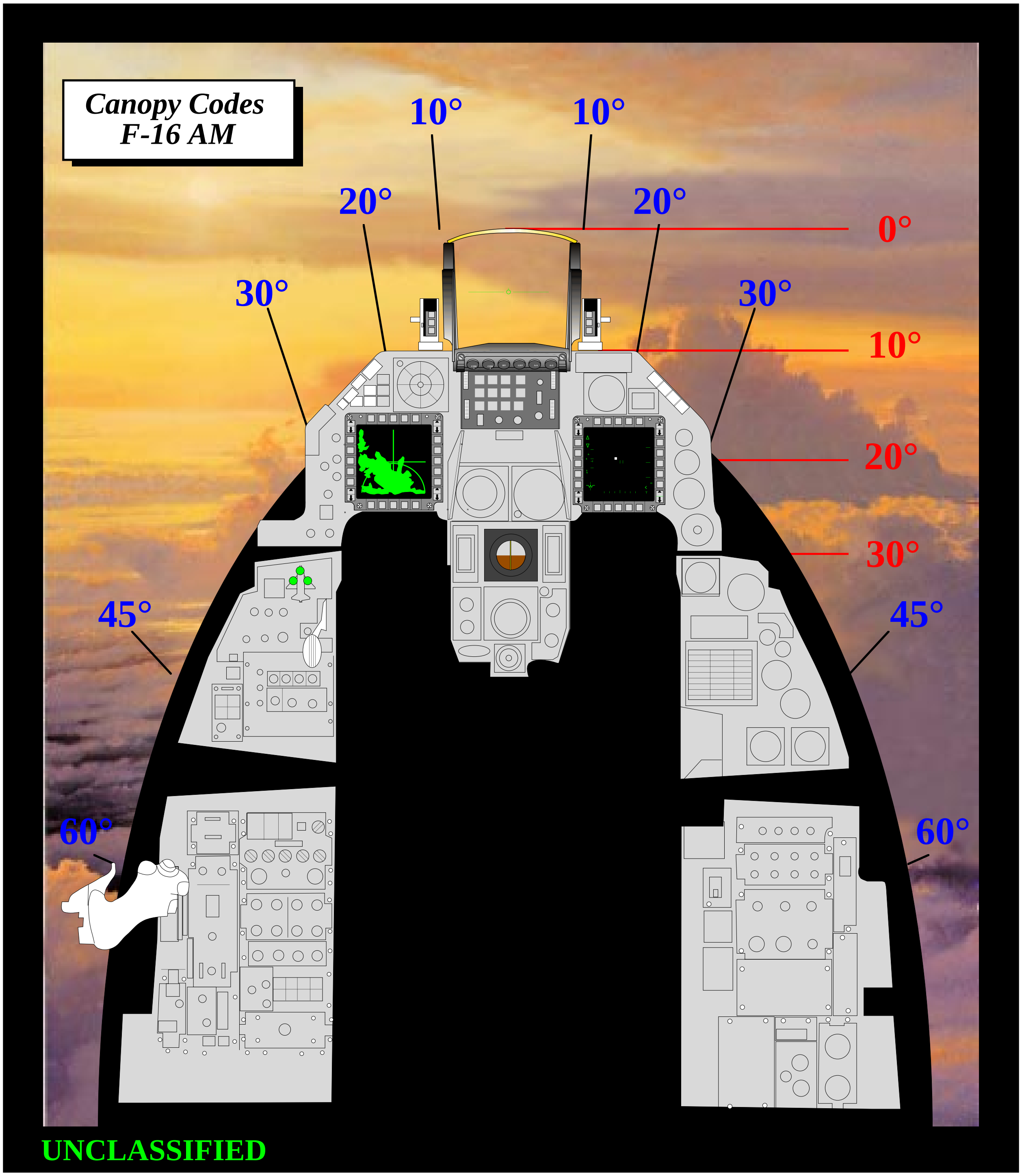
- Position awareness of other flight members.
- Early position awareness of the threat and the attack axis.
- Communication of offensive and defensive information to the flight.
- Targeting and weapons employment prior to threat attack.
- The ability to prosecute the attack and/or disengage.

3.7.2. Formations. Visual formations can provide for all of the elements of a sound mutual support contract. Additionally, visual contact with other element members is critical in a visual fight. A visual formation is a common choice, because you cannot assume the enemy is beyond visual range (BVR). Visual formations are easy to fly, provide a common and reliable reference for communication and targeting, mass of firepower, and most importantly, provide immediate position awareness of supporting fighters (**Figure 3.5.**, Canopy Codes F-16AM).

3.7.3. Formation Selection. The basic combat formation employed by tactical fighters is the four-ship flight. The two-ship element is the basic fighting unit. The wingman's primary duty is to fly formation on his leader and to support the lead at all times. The wingman is to clear the area and perform his portion of the briefed mission. A four-ship flight consists of two elements directed by the four-ship flight lead, increasing the mutual support of all. Considering the variety of air and surface threats, terrain, weather, target arrays, and mission objectives that will be encountered in carrying out a wide range of wartime taskings, there is a need for both Line Abreast and Trail formations. Each of these types of tactical formations has unique strengths and weaknesses.

3.7.3.1. Line Abreast Considerations. Where the major threat is from enemy fighters, it provides optimum visual cross coverage and good position for rapid maneuvering and mutual support for counter attack. Also, it diminishes the opportunity for a ground threat to be alerted by the leader's overflight and carry out a successful engagement on the wingman. (At ingress airspeeds gunners have an additional 2 to 4 seconds reaction time on a wedge wingman.) Line abreast makes it easy for the leader to check on the position and status of all wingmen. It also lends itself well to simultaneous attacks by the leader and wingmen against known enemy targets with distance deconfliction and turning room. On the other hand, line abreast formations have certain disadvantages. It is not practical to fly at extremely low altitude with random maneuvering. Moreover, line abreast is difficult for wingmen to achieve spacing on the leader for a sequenced attack, particularly where target location is not precisely known.

Figure 3.5. Canopy Codes F-16AM .



3.7.3.2. Trail Considerations. Trail formations provide less 6 o'clock threat lookout coverage and have less flexibility in initial maneuvering to counter A/A attacks behind the 3/9 line. On the strength side, Trail formations can be flown successfully at lower altitude, especially in mountainous terrain, because the wingman can keep both the leader in sight and adequately scan approaching terrain. In certain threat scenarios, extremely low-altitude flight can be a critically important advantage. Trail formations also allow for good offensive air capability against a forward quarter threat and good maneuvering potential. Trail also provides much greater maneuvering flexibility as wingmen can handle turns of any magnitude by delayed maneuvers. Such maneuvering may be required to pinpoint targets at the last minute, and also to evade pop-up ground threats such as automatic weapons fire. Finally, Trail formations also have advantages for multiple attacks against the same target or target array (not all threat scenarios call for single pass tactics.

3.7.4. Visual Lookout. Visual lookout is a priority task for all flight members, flight leads as well as wingmen. Historically, 90 percent of all A/A kills were achieved due to undetected attacks. Visual formations evolved throughout the years in an attempt to visually clear and deny the enemy an unseen entry. In addition to visual detection, survivability increases when each flight member has a potential for timely assistance by using the radio or weapons. The amount of time spent maintaining visual contact, or formation position, influences the ability to detect a threat visually or by other means (radar, ground-controlled intercept (GCI), etc.). In addition, the dynamics of ACM often drive you to a position where providing timely assistance is difficult. Examples of this can be found at **Figure 3.6.**, 6 O'clock Visual Coverage, and **Figure 3.7.**, Aircraft References for 6 O'clock Look Angles.

3.7.5. Formation Responsibilities. The flight lead assigns responsibilities for each flight member. Dividing responsibilities ensures each pilot has a manageable number of tasks to perform. Flight member normal responsibilities are:

- Number One: Primary planner and decision-maker, primary navigation and radar lookout, visual lookout as other responsibilities allow, and primary engaged fighter, if practical.
- Number Two: Maintain formation position and visual lookout. Radar awareness and navigation position awareness, as other responsibilities allow.
- Number Three: Maintain formation on the lead element, secondary navigation and radar monitor, and visual lookout as other responsibilities allow.
- Number Four: Same as Number Two.

3.7.6. Time-Sharing. The goal on every low-level training mission should be to improve the development of the time-sharing cross-check. Practice and discipline are essential to maximizing visual mutual support. On each mission, pilots must start with the basic NEAR ROCKS, FAR ROCKS, CHECK SIX pattern and build up the visual search arena as allowed by task saturation, threat and flight conditions. When encountering extremely rough terrain, defensive reactions, navigation turns, etc., drop the lowest priority sectors in order. There will be times, such as hard turns, when only NEAR ROCKS can be cross-checked. The key is to quickly re-establish the cross-check one sector at a time as tasks permit.

Figure 3.6. 6 O'clock Visual Coverage.

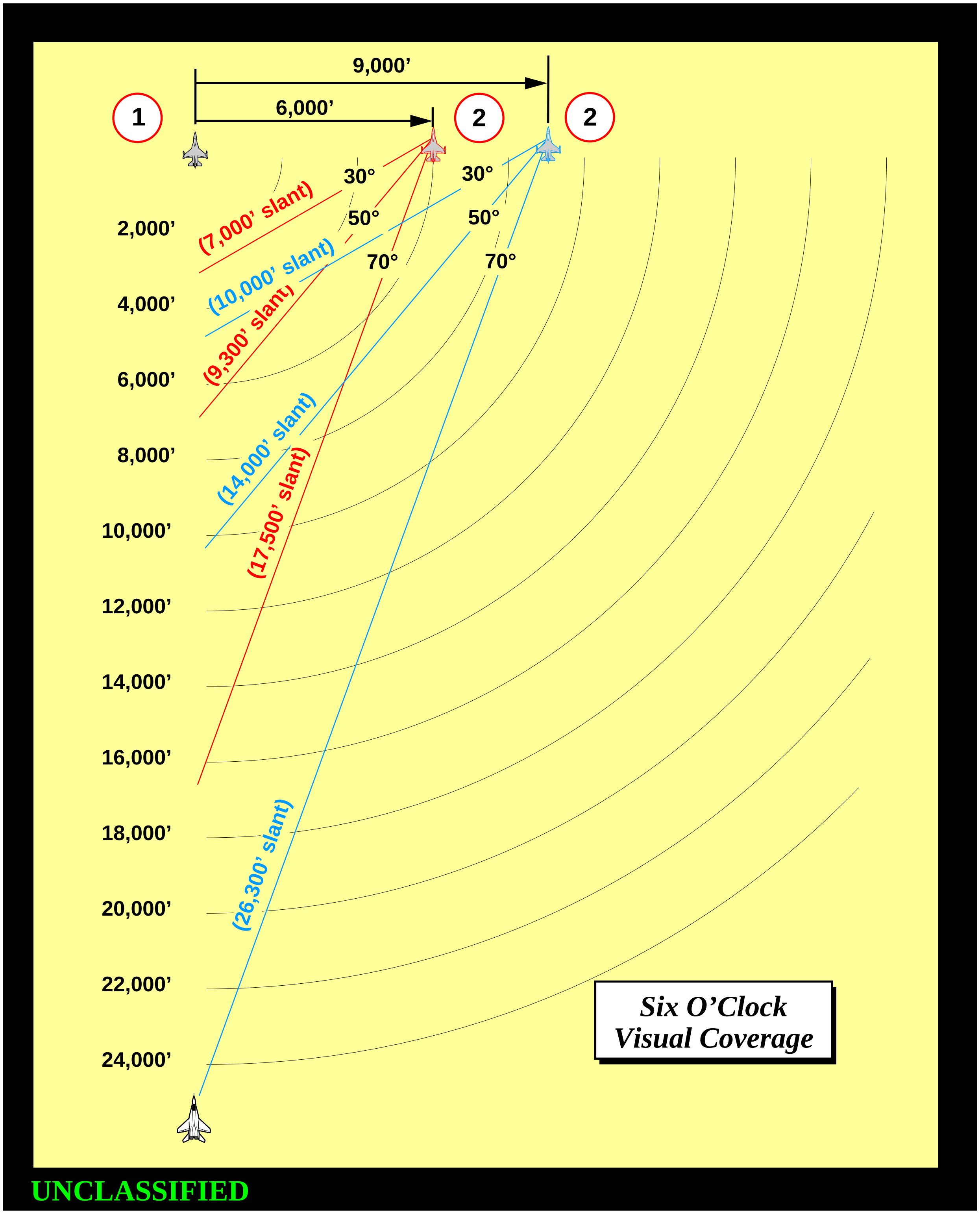
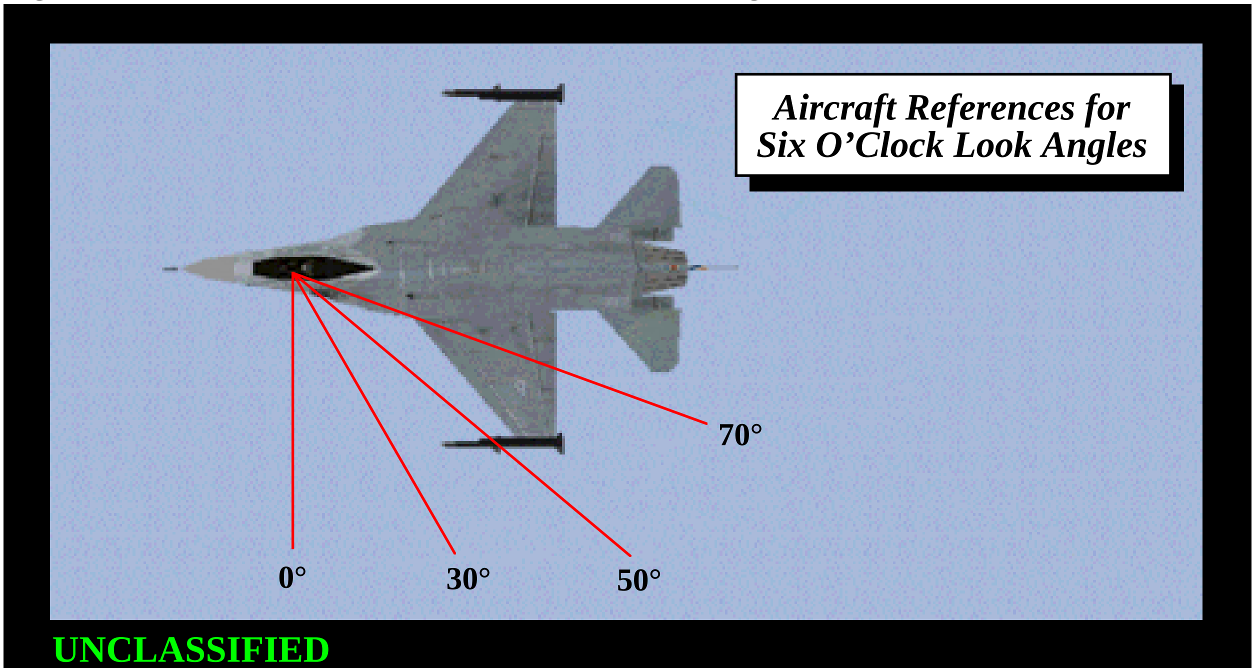


Figure 3.7. Aircraft References for 6 O'clock Look Angles.

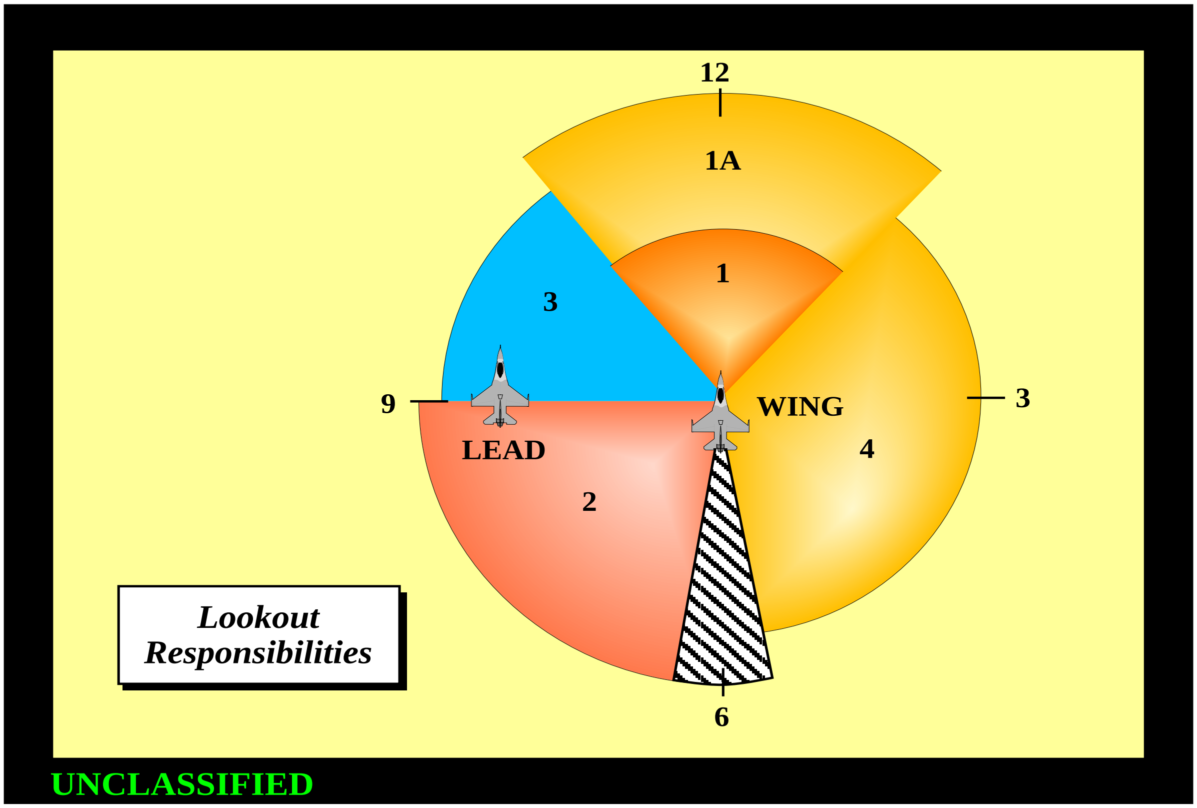


3.7.7. Lookout Responsibilities. Although the pilot has a myriad of responsibilities, one task can be performed at a time. Therefore, time-sharing plan must be employed to quickly and efficiently accomplish many tasks. The following is an example of a time-share plan for lookout responsibilities. The airspace around the aircraft is divided into sectors and each sector is assigned a priority based on lookout responsibilities (**Figure 3.8.**, Lookout Responsibilities). This plan is developed from a perspective of Number Two in a four-ship, but the principles apply to all positions in the flight.

- Sector 1: This is the hub of the cross-check. It is divided into two parts. Sector 1 is NEAR ROCKS, the rocks that will affect the flight path in the next 10 to 15 seconds. This sector is the highest priority sector and is the center of the cross-check. NEAR ROCKS are the ones that present an immediate threat. Sector 1A is FAR ROCKS, the terrain that will affect future maneuvering. Pilots that look ahead at the FAR ROCKS are smooth in their maneuvering to maintain position or navigate because they see the mountain peaks and valleys in time to make small corrections.
- Sector 2: Besides avoiding the ground, the next most important area for lookout space is inside the flight's 6 o'clock. Sector 2 allows Number Two to monitor formation position and check lead's 6 o'clock. Sectors 1, 1A, and 2 make up the basic cross-check NEAR ROCKS, FAR ROCKS, CHECK SIX.
- Sector 3: Once these responsibilities are completed, other areas can be brought into the cross-check. The next sector is inside the flight ahead of the 3/9 line. Searching this area can detect bandits in a conversion, as well as surface-to-air missiles (SAM) that may be fired from the front quadrant. Sector 3 is lower priority than Sectors 1, 1A, and 2; therefore, it should be searched less frequently. NEAR ROCKS and FAR ROCKS must be checked during each search cycle. The frequency of search is dependent on pilot task saturation.

- Sector 4: When proficient enough, expand the search to a 360-degree lookout by picking up Sector 4. Sector 4 is outside the flight, ahead or behind the 3/9 line. This sector is the lowest priority; the wingman owes it to the flight lead to provide inside the flight lookout before dedicating time to this sector.

Figure 3.8. Lookout Responsibilities.



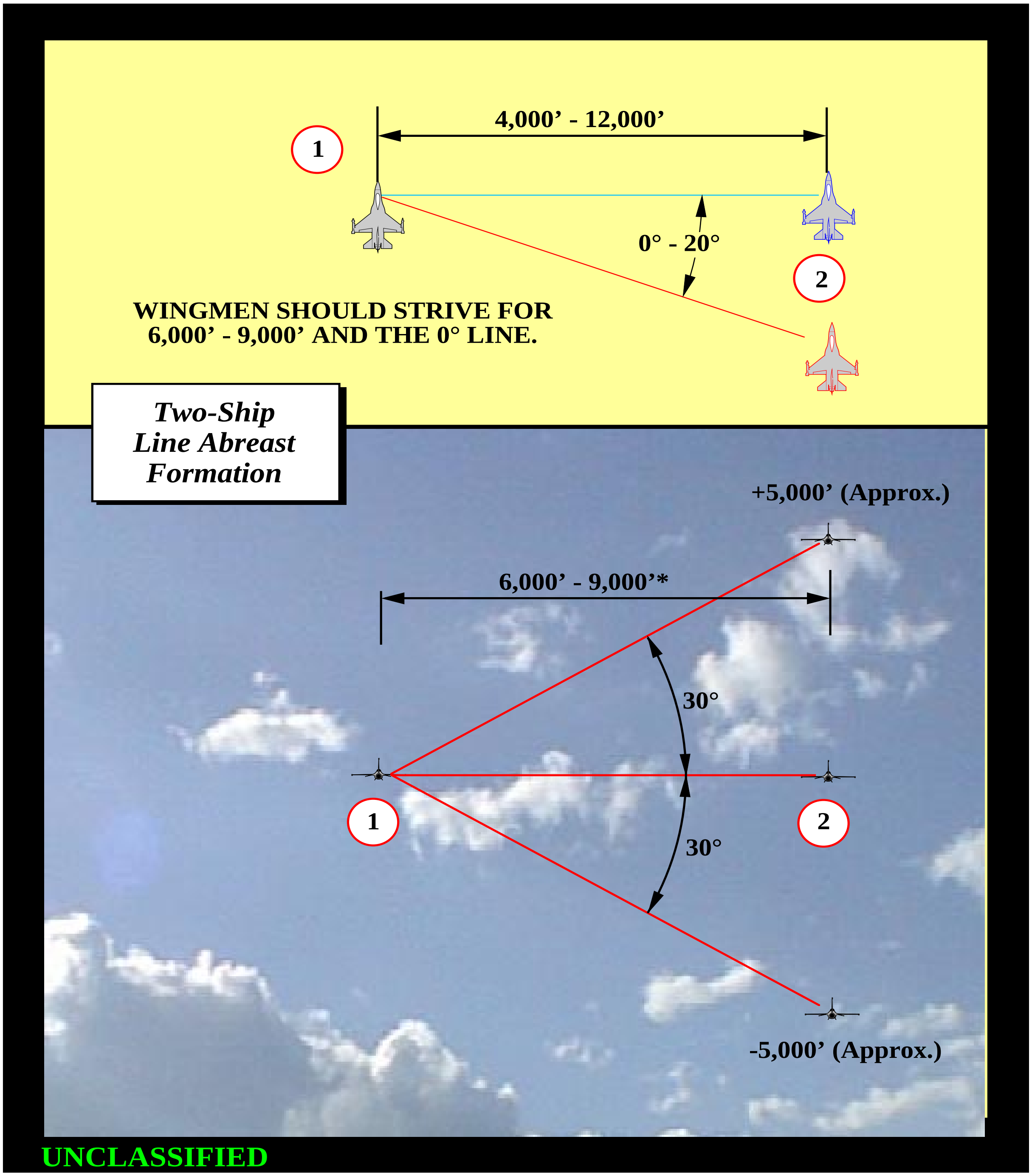
3.7.8. Radar Integration and Cockpit Tasks. A complete understanding of **paragraph 3.7.7** will answer the question "Where does the radar fit into the cross-check?" Flight position will determine where to incorporate radar lookout. As lead or Number Three, it should be part of Sector 3. As Number Two or Number Four, the radar should be after Sector 4. Performing cockpit tasks is the next problem. The best plan is to accomplish as many tasks as possible prior to entering the low-altitude regime. Switch errors are often made in the heat of battle. When switch changes are required, substitute them for a cross-check sector search. For pacing, do one task, then reference the flight path before moving to another task.

3.8. Two-Ship Formations.

3.8.1. Line Abreast. Line Abreast formation is a position 0 to 20 degrees aft, 4,000 to 12,000 feet spacing, with altitude separation (**Figure 3.9.**, Two-Ship Line Abreast Formation). At low altitude, the wingman should fly no lower than lead.

3.8.1.1. Unless further defined by the flight lead, wingmen will fly from 6,000 to 9,000 feet and strive for the 0-degree line. The 6,000 to 9,000 feet position provides optimum visual and firepower mutual support for threats from the beam and 6 o'clock positions.

Figure 3.9. Two-Ship Line Abreast Formation.



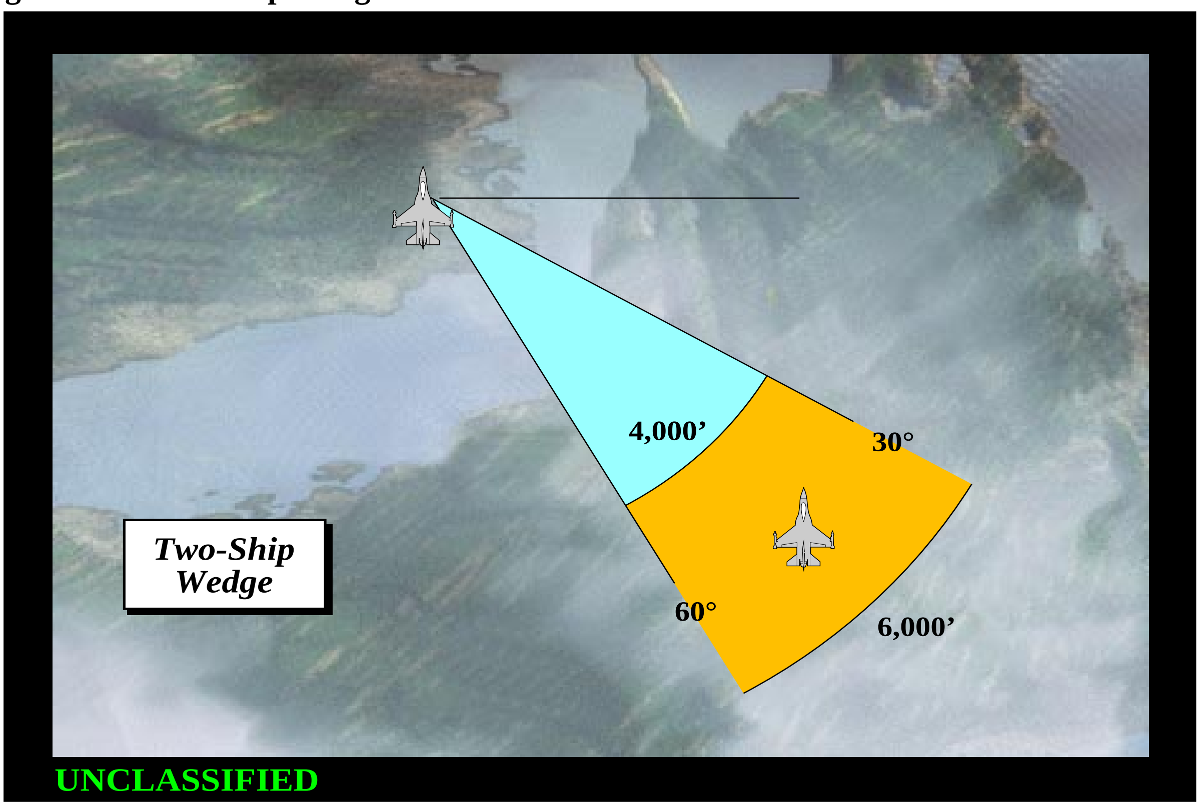
3.8.1.2. The flight lead may tailor the parameters of this formation to meet particular situations or requirements. For example, in poor visibility conditions at low altitude, the wingman may be briefed to fly 4,000 to 6,000 feet lateral spacing. For certain A/A scenarios, the briefed lateral spacing may be 9,000 to 12,000 feet to enhance 6 o'clock visual coverage while complicating the enemy's visual acquisition of all aircraft in the formation. Wingmen need to maintain a formation position which allows performance of other responsibilities and not concentrate 100 percent of their attention on flying formation.

3.8.1.3. Each pilot must be in a position to detect an adversary converting on the wingman's stern prior to that adversary reaching firing parameters. Against an all-aspect, all-weather adversary this may not be possible. F-16 rearward visibility field of view (FOV) is not a limiting factor, as it is in most other aircraft.

3.8.1.4. This formation allows element members to be in position to quickly bring ordnance to bear when a threat is detected. A vertical stack of 2,000 to 5,000 feet, when applicable, minimizes the chance of simultaneous detection by a bandit.

3.8.2. Wedge. Wedge positions the wingman 30 to 60 degrees aft of the leader's 3/9 line, 4,000 to 6,000 feet back. The flight lead may extend the formation spacing out to 12,000 feet to meet particular situations or requirements (**Figure 3.10.**, Two-Ship Wedge).

Figure 3.10. Two-Ship Wedge.

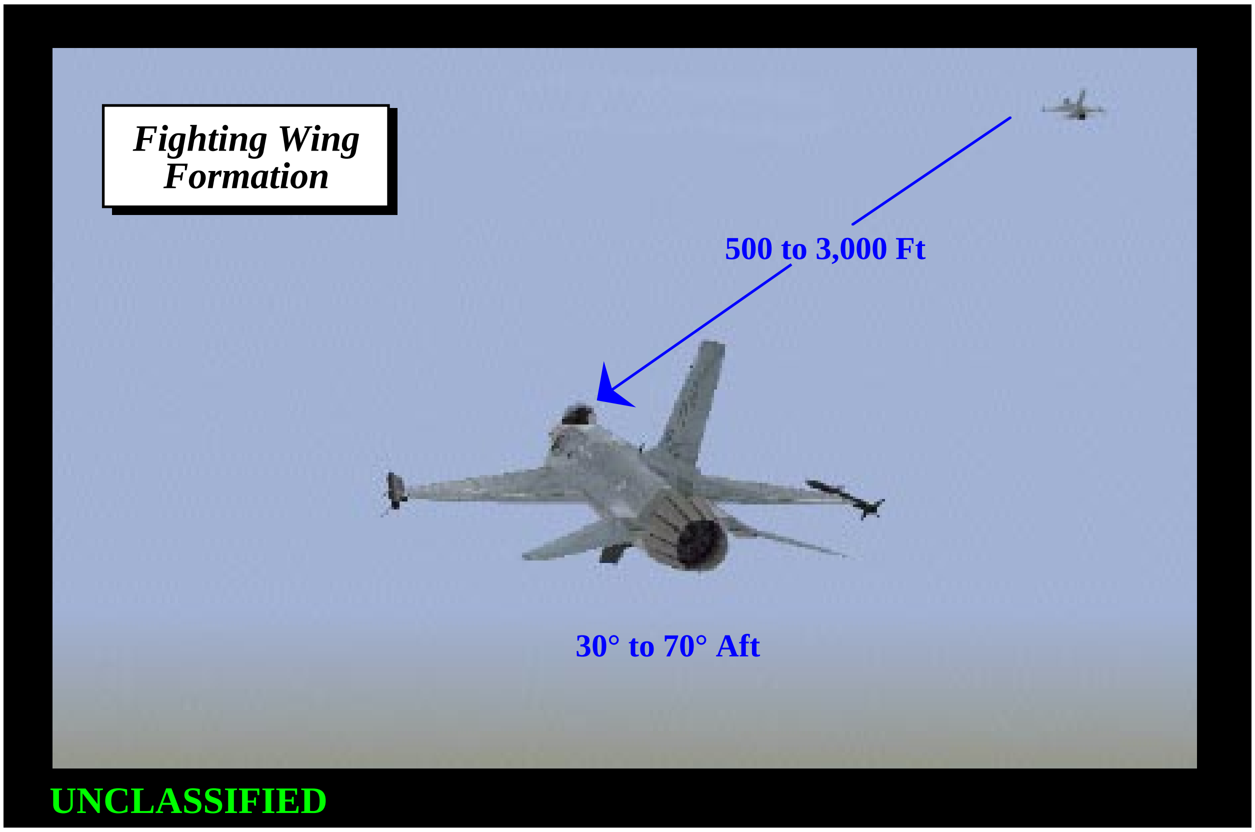


3.8.2.1. The advantages of wedge are that the leader is well protected in the 6 o'clock area and is free to maneuver aggressively. The wingman may switch sides as required during turns. The wingman may also switch sides as required to avoid terrain, obstacles or weather but must return to the original side unless cleared by the leader.

3.8.2.2. The most significant disadvantage of the wedge is that it provides little to no 6 o'clock protection for the wingman. Lead changes, if required, are difficult to execute.

3.8.3. Fighting Wing. This formation, flown as a two-ship, gives the wingman a maneuvering cone from 30 to 70 degrees aft of line abreast and lateral spacing between 500 to 3,000 feet. Number Two maneuvers off lead and uses cutoff as necessary to maintain position. This formation is employed in situations where maximum maneuvering potential is desired. Arenas for use include holding in a tactical environment or maneuvering around obstacles or clouds (**Figure 3.11.**, Fighting Wing Formation).

Figure 3.11. Fighting Wing Formation.



3.8.3.1. Advantages:

- The formation allows the element to maintain flight integrity under marginal weather conditions or in rough terrain.
- Allows for cockpit heads-down time for administrative functions when in a low-threat arena where hard maneuvering is not required.

3.8.3.2. Disadvantages:

- Poor to nonexistent 6 o'clock coverage.
- Easy detection of formation by single threat.

3.9. Four-Ship Formations. The four-ship is under control of one flight lead and is employed as a single entity until such time as it is forced to separate into two elements. At no time should an element sacrifice element integrity attempting to maintain the four-ship formation. Each two-ship element should have its own radar and visual plan so that no changes will be required if the four-ship is split into two-ships.

3.9.1. Box/Offset Box. In Box formation, elements use the line abreast maneuvering and lookout principles. The trailing element takes 1.5 to 3 NM separation, depending on terrain and weather. The objective of the spacing is to give separation to avoid easy visual detection of the whole formation, while positioning the rear element in a good position to immediately engage an enemy converting on the lead element. Because the F-16 is difficult to see from a direct trail position, a slight offset will facilitate keeping sight of the lead element. Use of A/A tactical air navigation (TACAN) between the elements, and the radar in the rear element, will help keep the proper spacing. Element leaders initiate formation maneuvers. Number Three maneuvers to achieve prebriefed spacing on the lead element (based on threat, mission, weather, etc.). Flight leads may modify wingmen position to Wedge or Fighting Wing if desired (**Figure 3.12.**, Four-Ship Offset Box).

NOTE: In an ATC environment, if standard formation is required, the trailing element should fly closer than 1 NM and wingmen from 4,000 to 6,000 feet.

3.9.1.1. Advantages:

- The formation provides excellent mutual support and lookout.
- The rear element is positioned to engage an adversary making a stern conversion on the lead element.
- It is difficult to visually acquire the entire flight.
- Element spacing for an attack is built into the formation.

3.9.1.2. Disadvantages:

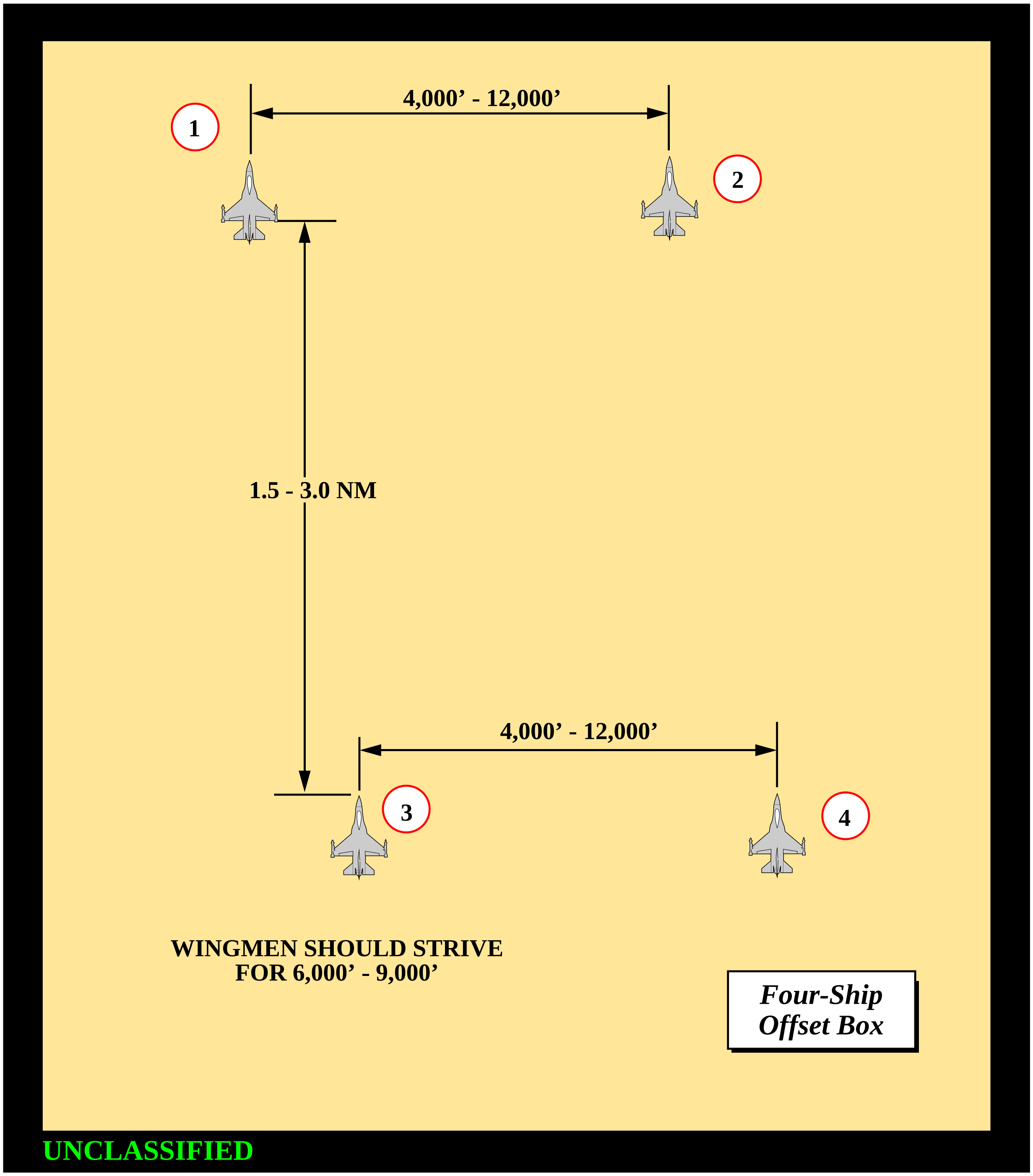
- The formation is difficult to fly in poor visibility and rugged terrain.
- Depending on position, the trailing element may be momentarily mistaken as a threat, especially if staggered too much off to one side.

3.9.2. Fluid Four. Element leads fly line abreast, with wingmen in Fighting Wing. Number Three maneuvers off Number One. Number Two and Number Four maneuver off their element leaders to maintain the outside of the formation. Element leads are responsible for deconfliction of elements when crossing the opposing element's 6 o'clock. At medium altitude, wingmen should stack away from the other element when turning (**Figure 3.13.**, Fluid Four Formation.)

3.9.2.1. Advantages:

- Inexperienced wingmen are kept close for ease of maneuvering.
- Four-ship maneuverability is good.
- Formation provides concentration of force.
- Easily converts to three-ship when one aircraft falls out.

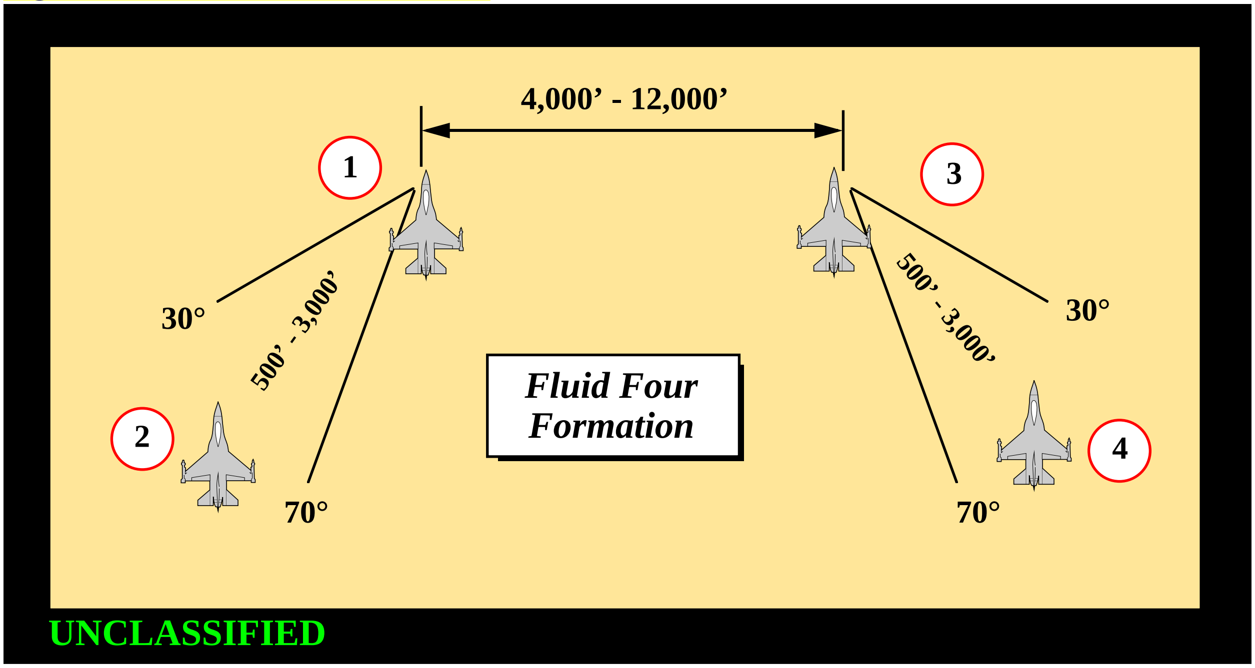
Figure 3.12. Four-Ship Offset Box.



3.9.2.2. Disadvantages:

- Adversary can acquire all four aircraft.
- Defensive maneuvering rapidly becomes confusing due to the proximity of aircraft.
- Cumbersome to maneuver at low altitude in rough terrain.

Figure 3.13. Fluid Four Formation.



3.9.3. Spread Four. Element leads maintain line abreast, wingmen position themselves 0 to 30 degrees back from their element leads and 6,000 to 9,000 feet spread. Each element uses fluid maneuvering. Number Three flies off Number One (similar to Fluid Four). The elements are not always required to be line abreast. On some occasions they may be briefly in trail (**Figure 3.14.**, Spread Four Formation).

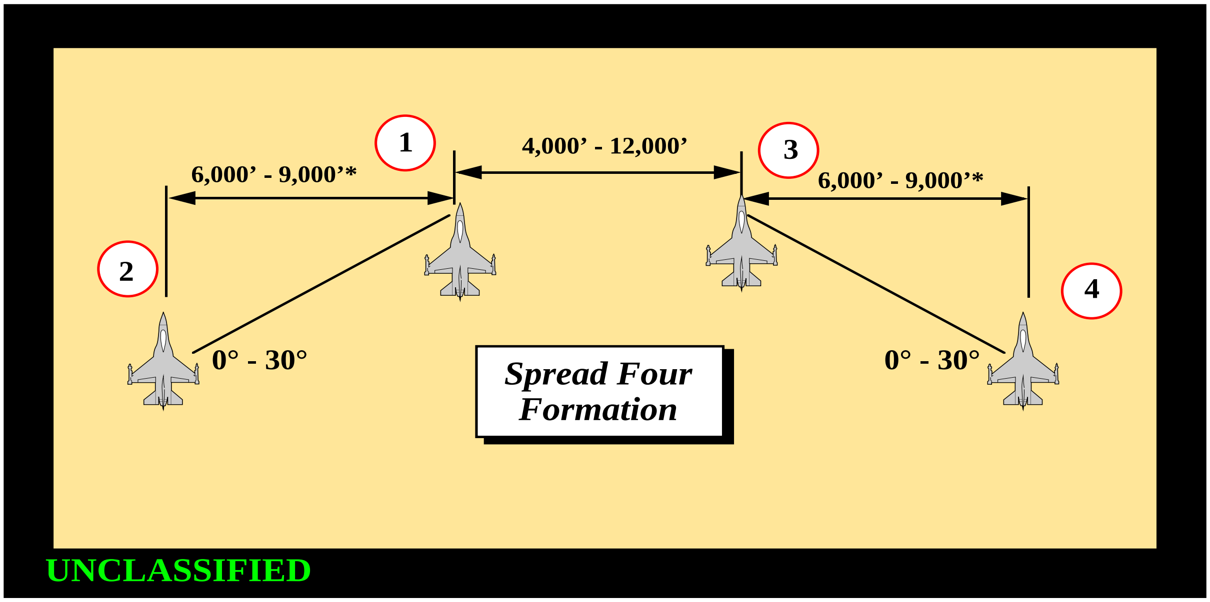
3.9.3.1. Advantages:

- Spread Four formation makes it difficult for an adversary to visually acquire the entire flight at once.
- Firepower is maximized for BVR weapons employment.

3.9.3.2. Disadvantages:

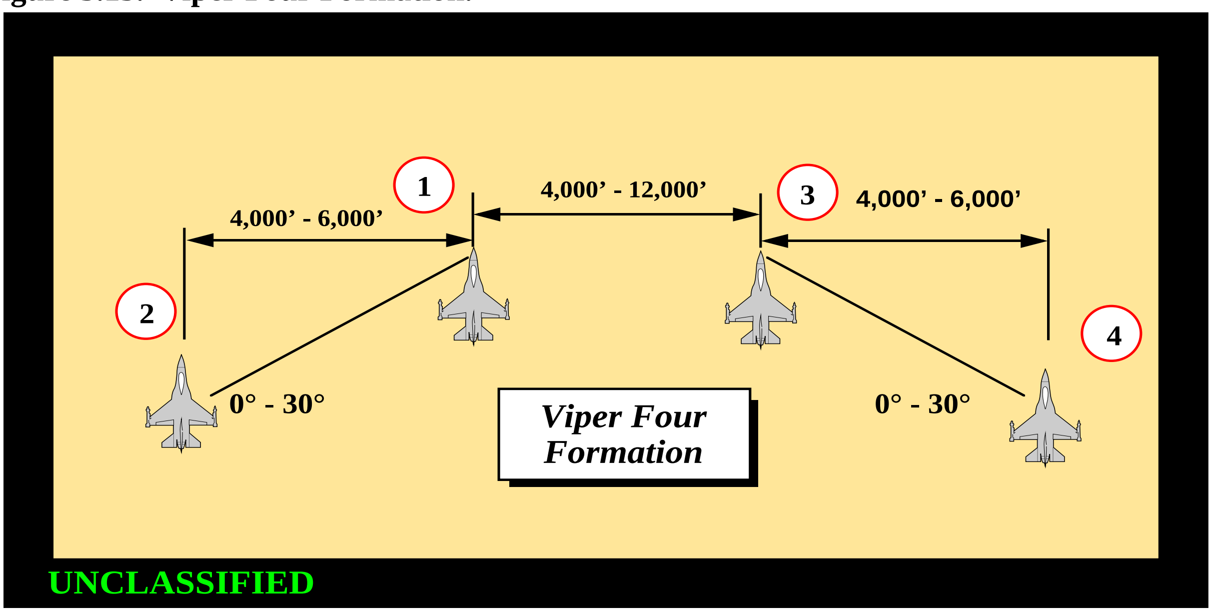
- Maneuvering is difficult if the line abreast position is maintained.
- Very difficult for wingmen to fly at low altitude.

Figure 3.14. Spread Four Formation.



3.9.4. Viper Four. Element leads maintain line abreast, wingmen position themselves 0 to 30 degrees back from their element leads and 4,000 to 6,000 feet spread; this is the same as Spread Four, but wingman fly a tighter position (**Figure 3.15.**, Viper Four Formation).

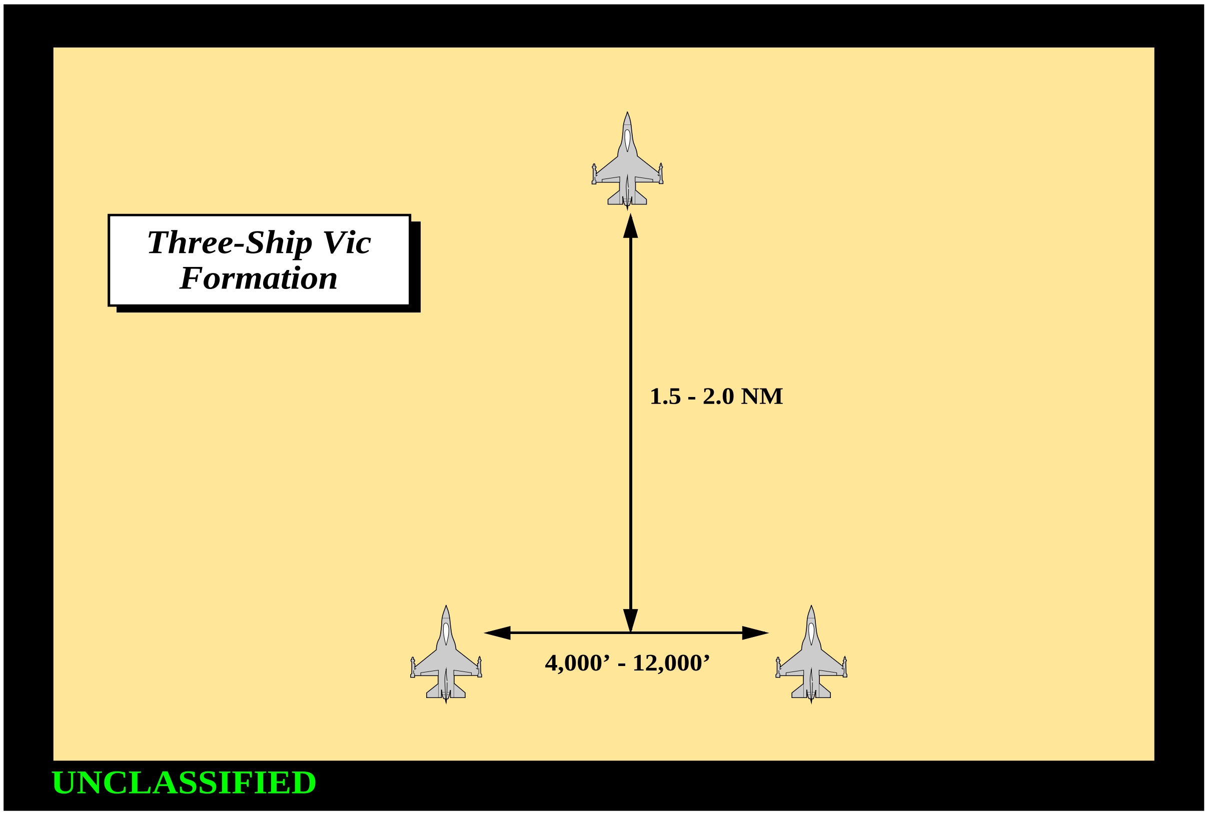
Figure 3.15. Viper Four Formation.



3.10. Three-Ship Formations. There may be occasions when a priority mission requires maximum available aircraft and a three-ship is the only alternative. Mutual support requirements to ensure survivability and recovery are paramount; therefore, a three-ship contingency should be briefed on all four-ship missions. On these occasions, the following three-ship formation discussion is applicable.

3.10.1. Vic Formation. Lead flies 1.5 to 2 NM in front of the trailing element. The lead aircraft maneuvers as desired. The trailing element uses line abreast maneuvering to follow (**Figure 3.16.**, Three-Ship Vic Formation).

Figure 3.16. Three-Ship Vic Formation.



3.10.2. Fluid Three. This is the same as Fluid Four with one aircraft missing. If the three-ship is caused by one aircraft falling out from a briefed four-ship, the following position changes should be followed: if lead falls out, Number Three assumes lead and Number Two moves to line abreast; if Number Three falls out, Number Four moves up to line abreast; if Number Two or Four fall out, there are no changes.

3.10.3. Three-Ship Spread. This is the same as Spread Four with one aircraft missing. Roles and responsibilities caused by fall out from a four-ship are the same as Fluid Three.

3.10.4. Viper Three. This is the same as Viper Four with one aircraft missing. Roles and responsibilities caused by fall out from a four-ship are the same as Fluid Three.

3.11. Tactical Turns. Turns may be communicated with either the radio or visual signals. Line Abreast formations compensate for inherent maneuvering problems with specialized prebriefed procedures. These include the type of turns to be made, the parameters at which these turns will be made, and the method by which these turns will be initiated. The turns consist of 45- to 90-degree delayed turns, in-place turns, cross turns, weaves, and check turns. The parameters for the turns are briefed by each flight leader and usually consist of the speed, "G," and the power required in the turn. The method of turn initiation is generally by radio call, wing flash, or check turn.

3.11.1. Radar/Visual Lookout. Individual areas of visual and radar responsibility should be briefed. The Line Abreast formation, because it is very common and widely accepted, has developed two traps which must be addressed:

- Trap 1. Assume that everyone flies formations exactly the same. Do not skip the formation section of the briefing, this will leave some doubt as to one or more of the necessary parameters or responsibilities. Squadron standards will help, but a thorough briefing on all planned or potential formations is the best. Do not leave the flight briefing with unresolved questions or if unclear on formation positions and responsibilities
- Trap 2. Tasking levels are not compensated for, when random maneuvering is required. Specifically, when the flight lead maneuvers unexpectedly, that forces the wingman to devote more time maintaining position instead of visual/radar search. Drifting left or right off course, large variances in airspeed, or altitude, can increase basic formation tasking to the exclusion of mission tasks. A 10-degree check turn into a lagging wingman may be preferable to the time and effort required for that wingman to drive forward to the briefed position. Exact headings are not critical; however, mutual support responsibilities are vital. This is not to say a leader flies off the wingman. The flight lead can make the wingman more effective by being considerate. If the situation requires many random turns, a more maneuverable formation should be flown.

3.11.2. Maneuvering With Unrestricted Communication. When the radios are available, some flight leads will use them. Tactical turns will be initiated by the flight lead. The preparatory command for a turn is: flight call sign and the command of execution is the type turn called. EXAMPLE: "FALCON ONE, 90 RIGHT." Delayed turn types are assumed, unless overridden in flight. EXAMPLE: "FALCON ONE, HOOK RIGHT." **Figure 3.17.**, Delayed 90-Degree and Hook Turns and **Figure 3.18.**, Delayed 45-Degree/Cross Turn/Check Turns, are examples of delayed turns.

Figure 3.17. Delayed 90-Degree and Hook Turns.

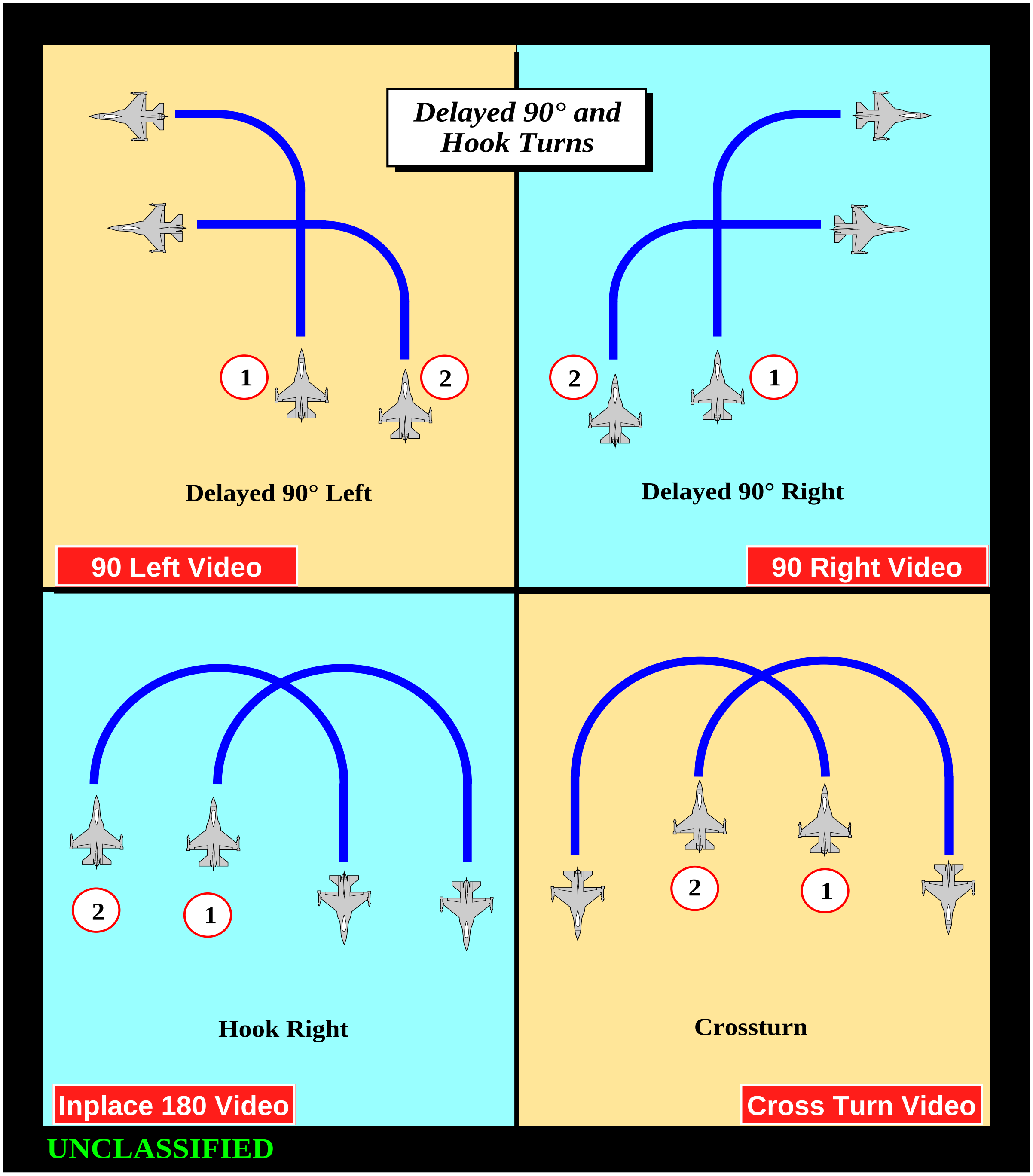
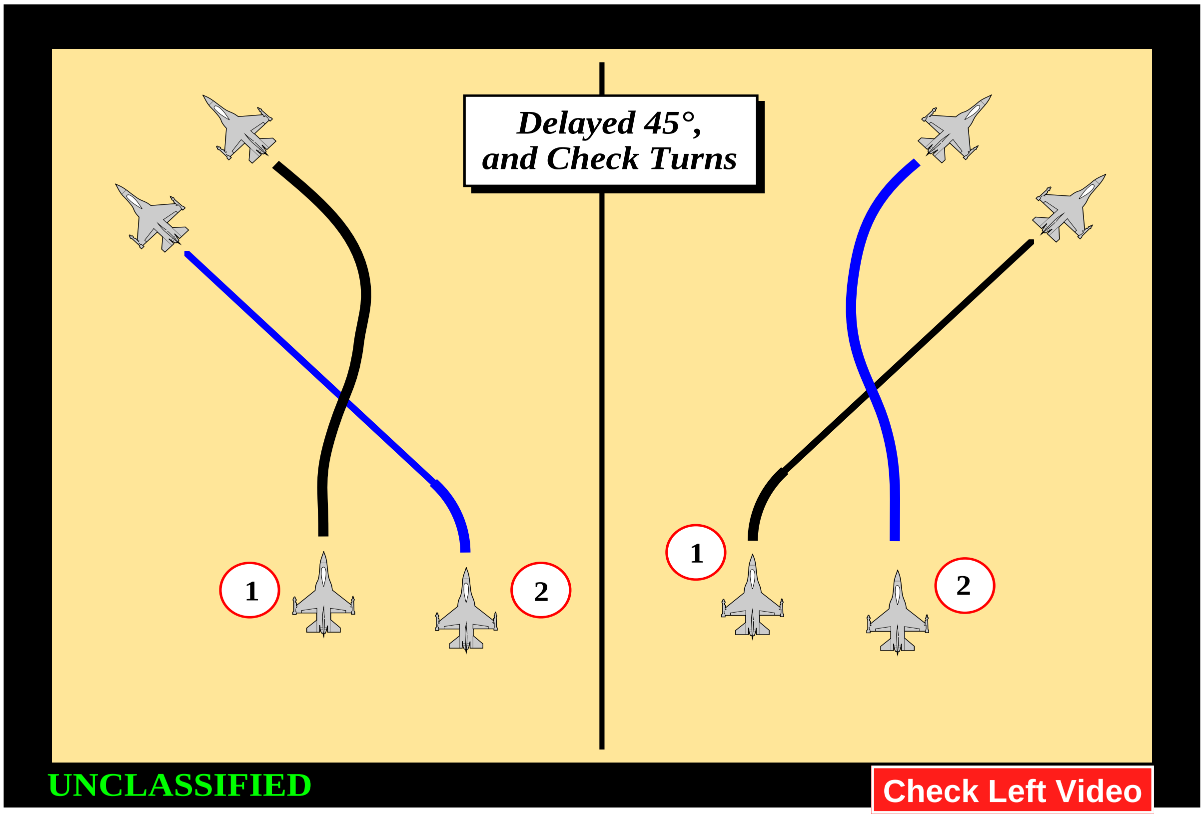


Figure 3.18. Delayed 45-Degree/Cross Turns/Check Turns.



3.11.3. Radio Silent Maneuvering. There may be times when radio silent procedures are used to maneuver the flight. Under these conditions certain variables must be held to a standard. The basic "contract" between flight members is:

- The wingman will always strive for the briefed position.
- The aircraft caught in front after the turn is responsible for regaining the briefed position (Weave, Shackle, etc.)
- The wingman does not exceed 90 degrees off the leader's heading.
- Lead and wingman will use the same turns at all altitudes (normally, Mil power and 4-G turns).
- Lead initiates all turns.
- Lead will signal all turns away from the wingman (wing flash, check turn, etc.).
- A turn into the wingman is signaled by leads turn into the wingman.
- If at low altitude, the wingman will not stack lower than the leader.
- During tactical radio silent turns at low altitude, the man being turned into will do a 30-degree check turn away from the other man to deconflict flight paths and/or signify acknowledgment. At medium or high altitude, this check turn may be omitted, at flight lead discretion. Flight leads are expected to specify when check turns will not be used. Also, flight members must differentiate between radio silent commands (the "big"

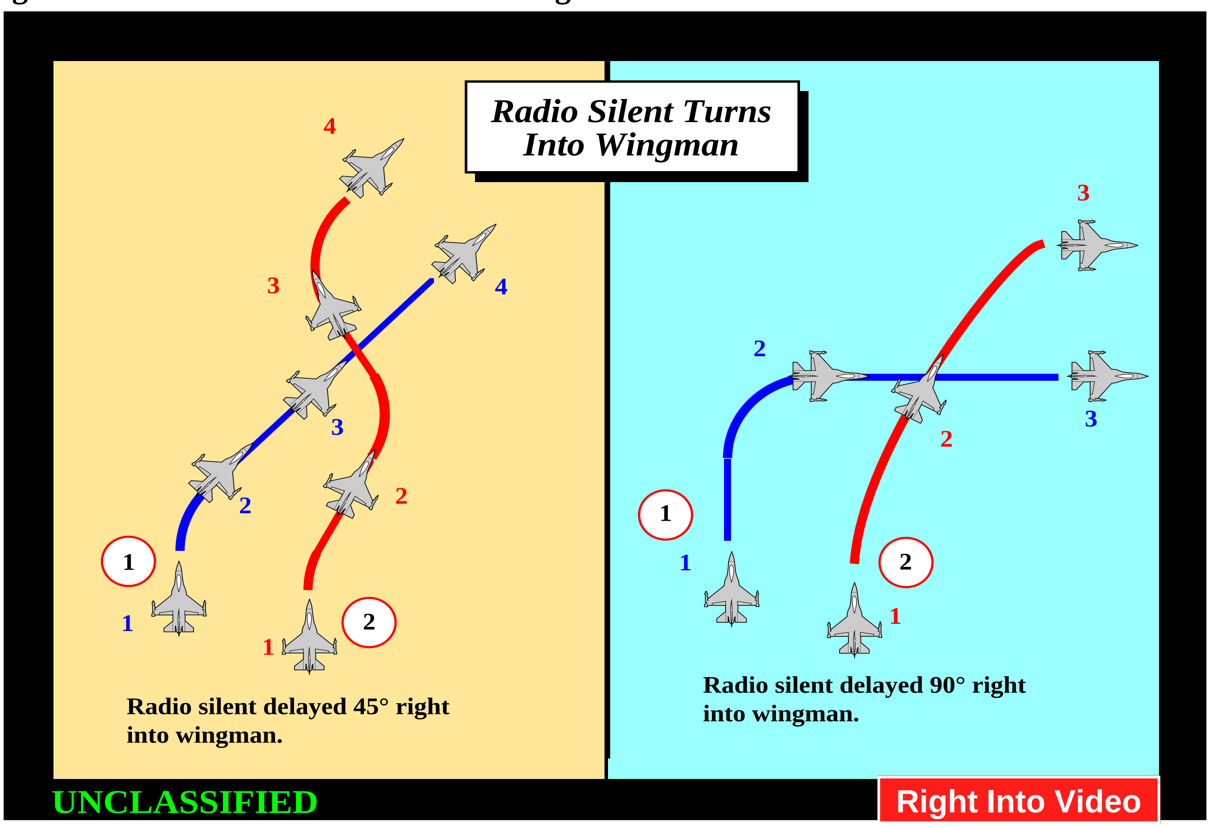
wing flash) and belly checks, or terrain masking. (***NOTE:*** Nose rate movement may be the best way to differentiate.)

- Visual lookout responsibilities shift forward as lower altitudes are encountered. The percent of time clearing for airborne threats is reduced at low altitude.

3.11.3.1. Turns Into the Wingman (**Figure 3.19.**, Radio Silent Turns into Wingman).

- Lead initiates the turn by turning into the wingman, normally at Mil power and a sustained 4 G's.
- Wingman checks 20 to 30 degrees and searches the new six through lead.
- Wingman assumes a 90-degree turn and turns to regain line abreast, if lead turns through the wingman's 6 o'clock.
- Wingman now weaves to line abreast (delayed 45- to 60-degree turn), if lead rolls out short of passing through the wingman's 6 o'clock.
- A 180-degree turn will be accomplished in increments of two delayed 90-degree turns, if required.

Figure 3.19. Radio Silent Turns Into Wingman.

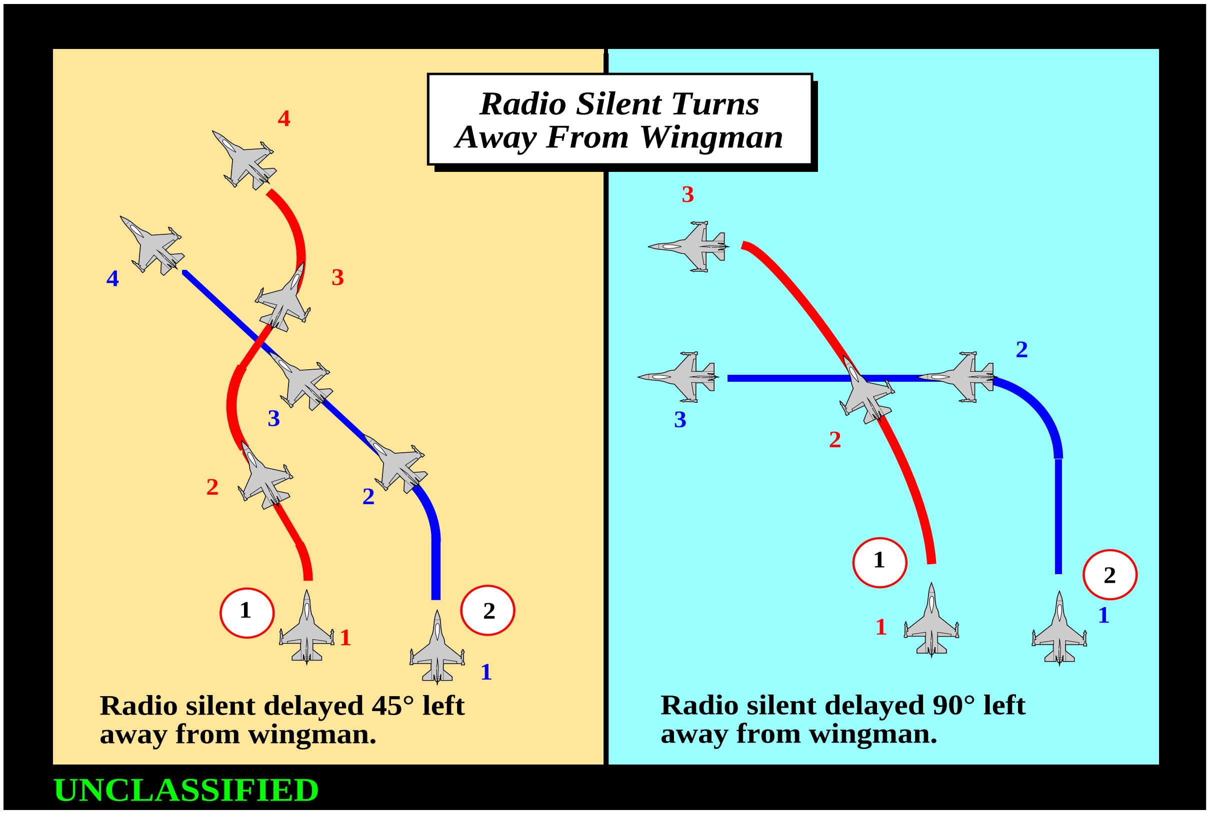


3.11.3.2. Turns Away from the Wingman (**Figure 3.20.**, Radio Silent Turns Away From Wingman).

- Lead makes a check turn of approximately 30 degrees to signal the turn.
- Wingman sees the flash and begins the turn into lead using the briefed G and power setting (i.e., Mil, 4-G sustained, etc.).

- Lead wants a delayed 45- to 60-degree turn, lead turns into the wingman when the wingman obtains the desired heading. This is the wingman's command to roll out.
- Lead wants a delayed 90-degree turn, lead allows the wingman to continue turning through leads 6 o'clock.
- Lead wants to turn 180 degrees away, lead initiates the turn with a continuous 180-degree turn.

Figure 3.20. Radio Silent Turns Away From Wingman.



3.11.3.3. Check Turns.

- Lead turns to the desired heading using a gentle (less than a 2-G) turn.
- Wingman sees either a divergence or convergence and strives for line abreast using an “S” turn, vertical, or power.

CHAPTER 4

AIR-TO-AIR

4.1. Introduction. The purpose of the air-to-air (A/A) chapter is to review the basic training spectrum of the F-16 in aerial combat. This training consists of a series of mission elements and types that use a building block approach to reach the required level of proficiency. The areas include system and firepower, emitters, navigation, communications, and electronic countermeasures (FENCE) checks, basic fighter maneuvers (BFM), air combat maneuvers (ACM), intercepts, and gun employment. Aerial combat is by far the most difficult aspect of flight for the fighter pilot to understand and master. The arena is very dynamic, and the skills used must be learned over time. Personal desire and discipline will determine how quickly the individual masters the required skills. To reach the end objective of achieving a first look, first kill capability, the pilot will train in an environment which begins with the basics of a close-in engagement and then progress to beginning the engagement beyond visual range (BVR). The training will emphasize not only offensive skills, but high aspect and defensive skills as well. Furthermore, the training will transition from 1v1 maneuvering to operating as a team to provide mutual support as elements and flights.

4.2. System Checks. Avionics and weapons systems checks are an important part of basic A/A execution. Verification of the required systems to effectively employ in the air can mean the difference between a quick kill and a long drawn out engagement allowing the bandit's wingman to enter the fight and employ ordnance.

4.2.1. FENCE Check. In actual combat, most of the items in the FENCE check should be done prior to takeoff—a few at forward edge of the battle area (FEBA) crossing. For peacetime training this will vary (based on training area restrictions); portions of the check will be accomplished in or approaching the area, or not at all. Following a normal cockpit flow (left to right) (**Table 4.1.**, FENCE Check).

4.2.2. Weapon Systems Check. The purpose of the weapons systems check is two-fold: first, to check all avionics and missiles to be used in flight, and second, to practice the switchology to employ those systems and weapons. To minimize use of time and fuel, strive for an efficient and easily remembered sequence. Use the check to confirm multifunction display (MFD) setup and practice selecting the appropriate modes. This is a good time to review head-up display (HUD) and radar symbology. Early detection of any malfunctions or limitations that could limit mission effectiveness will help the pilot adjust the game plan prior to entering combat. Unless otherwise briefed, do not practice pickling missiles during the weapons check. This may lead to fratricide when carrying live missiles. Squadron standards should address execution specifics with or without live ordnance.

4.2.2.1. Preparation. Prior to starting the weapons system check ensure infrared (IR) missiles are cooled, the correct missiles and radar modes are selected in all positions of the DGFT/MSL OVRD switch, and Master Arm switch in simulate.

Table 4.1. FENCE Check.

FENCE Check	
· Tank inerting-as briefed.	
· TACAN-as briefed.	
· Lights-as desired.	
· COMM/MSL/RWR volume-as desired.	
· ECM controls-as briefed.	
· MODE SEL-depress (if you want the carets on the HUD).	
· HUD-intensity as desired.	
· Drift Cutout-as desired.	
· Contrast/Intensity-as desired.	
· RALT/ALOW-as required.	
· Master arm-SIM (ARM for combat or as briefed).	
· RWR-on, set as desired.	
· Radar-range and search volume set.	
· SEL JETT-tanks (rack) selected.	
NOTE: If tanks are loaded in an actual combat situation, select SEL JETT for your tanks and enter the combat arena with master arm ON to enable immediate jettisoning.	· These items should be checked if not already set during ground operations
· Chaff/flares-as required.	· UFC/FCNP.
· Secure voice-as briefed.	· Home Mode-correct steerpoint.
· VTR-as briefed.	· ATT/FPM-as desired.
· IFF-modes/squawks as briefed.	· VAH/VVI-as desired.
· AIM-9-cool.	· CAS/TAS/GS-CAS.
· MAV Power-On	· DED-in HUD.
· HARM Power-On	· Primary/manual reticle-set as desired.
· TGP-unstowed	· Radar level/channel/subset-as briefed.
· LASER-armed	· TGT HST-2 or as desired
· SMS-as briefed.	· NB/WB - as briefed
	· Master modes-verify programmed.
	· Publications and all loose items stowed/ strapped down.
	· G-suit-check
UNCLASSIFIED	

4.2.2.2. Execution. Position the aircraft between 1,500 and 3,000 feet aft of lead while avoiding leads 6 o'clock. Once established, maintain a slight airspeed advantage on the lead (+25 knots). Use geometry and power to control closure.

4.2.2.3. Verify proper HUD symbology. Use **Table 4.2.**, ACM Mode Check, as a reference to check all ACM modes for proper operation.

Table 4.2. ACM Mode Check.

ACM Mode Check
Check all ACM modes for proper operation
· BSGT, 10 x 60, 20 x 30, Slewable
· Verify HUD/SMS/MFD symbology in all modes
· Check TD box tracks target
· Check target locator line for proper indications and review your canopy codes
Confirm IR missile track quality
· Set missile tone volume high. Tone volume is proportional to the strength of the heat source, at maximum IR range tones are weaker than during the weapon system check
· Step through and uncage all missile seeker heads and check tones for self-track capability. Verify HUD symbology
· Depress the Z axis on the cursor enable switch and verify the AIM-9 goes to BORE, release it and reverify SLAVE
Verify Correct EEGS Operation
· Funnel movement consistent with aircraft maneuvers
· Level 5 EEGS symbology complete
· Complete visual range calibration and return to original formation
· If intending to simulate gun employment in flight, perform a trigger check in simulate with no flight members in the gun plane of fire (HUD and below)
· The radar warning receiver (RWR) should be on and checked for volume and azimuth while flying as target for the wingman's weapon systems check
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4.2.3. Air-to-Air Concepts. The maneuvers identified in this chapter are not pre-staged to arrive at the end game solution, but are combined as necessary based upon continual reassessment of the situation. The entire process of observing, predicting, and maneuvering is repeated until either a kill or disengagement has been achieved. This fundamental skill is necessary to perform all missions in the F-16.

4.2.4. Standard Setup Usage. Prescribed training setups facilitate a building block approach to teach these necessary skills. These training setups are designed to present a solvable problem and the ability to describe and teach the appropriate cues necessary to develop the mental picture and "stick and rudder" coordination required in BFM. As the pilot learns the basics of BFM from a controlled setup then progresses to varied setups and expands knowledge to the tactical implications of BFM. The pilot must always stay within his limits but try to expand his skills on each and every sortie. The end-game result of BFM training should prepare the pilot for multi-ship aerial combat.

4.3. Basic Fighter Maneuvers.

4.3.1. Objectives. The primary objectives of BFM are twofold:

4.3.1.1. Develop skill and confidence to maneuver the aircraft to a desired position in space, both for the dynamic A/A and air-to-ground (A/G) environment; and

4.3.1.2. Develop the skills to kill and survive in the aerial combat arena, specifically:

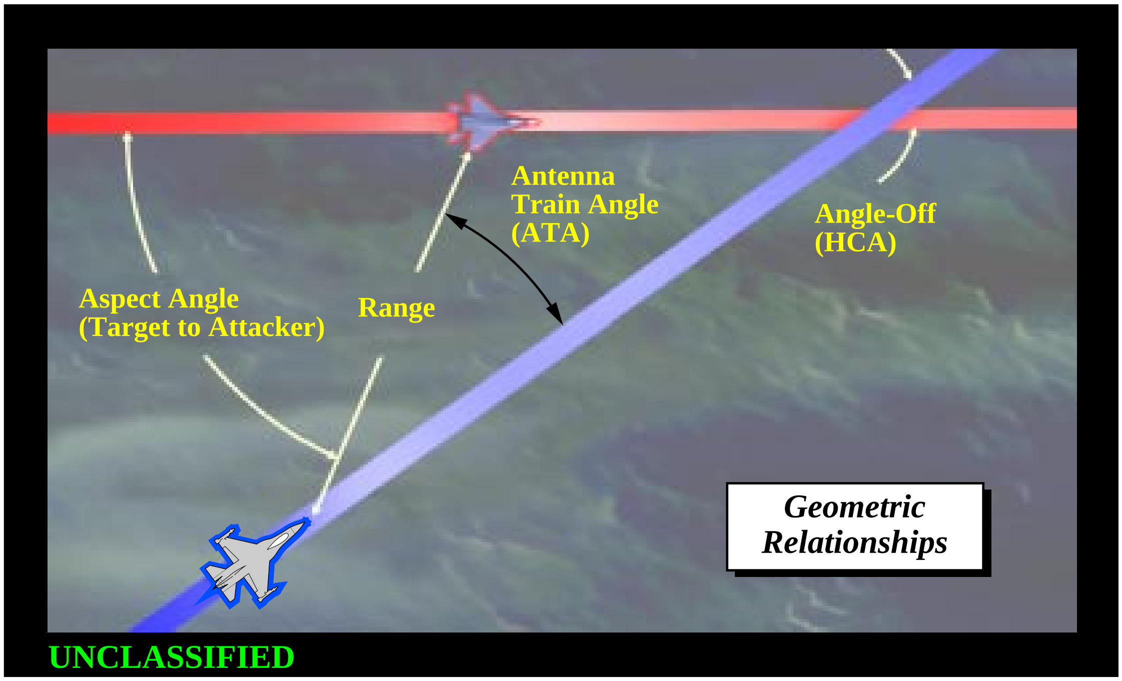
4.3.1.2.1. Maneuver the aircraft into weapons parameters to employ ordnance.

4.3.1.2.2. Maneuver to deny and defeat enemy ordnance. To be successful in BFM, pilots must understand the dynamics of aerial combat. These dynamics include: geometric relationship to the target, weapons employment zones (WEZ), turn and energy performance, and a basic understanding of flight physics.

4.3.2. Geometric Relationships. The geometric relationship of two aircraft can be analyzed from three perspectives: positional geometry, pursuit course, and the weapon envelope.

4.3.2.1. Positional Geometry. As shown in **Figure 4.1.**, Geometric Relationships, when discussing one aircraft's position relative to another: range, aspect angle (AA), angle-off (heading crossing angle [HCA]), and antenna train angle (ATA) are used. These four factors dictate which aircraft enjoys a positional advantage, and how much of an advantage.

Figure 4.1. Geometric Relationships.



4.3.2.1.1. Range. Range is the distance between two aircraft. Practicing ranging exercises as discussed in **Chapter 9** and experience with various sized aircraft build the skills to estimate range.

4.3.2.1.2. Aspect Angle. AA describes the relative position of the attacker to the target, without regard to the attacker's heading. It is defined as the angle measured from the tail of the target to the position of the attacker.

4.3.2.1.3. HCA/Angle-off. HCA/angle-off is primarily concerned with the relative headings of two aircraft. Angle-off is defined as the angular distance between the longitudinal axes of the attacker and the defender. Whenever the attacker is pointing at the defender, the AA and angle-off will be the same.

4.3.2.1.4. Antenna Train Angle. ATA is the number of degrees the defender is off the boresight of the attacker.

4.3.2.2. Pursuit Course. There are three available attack pursuit courses: lead, lag, and pure **Figure 4.2.**, Attack Pursuit Courses. The attacker's nose position or lift vector (Lv) will determine the pursuit course being flown. The pursuit course selection is easiest to determine if the attacker is in the defender's plane of motion (POM); the geometric plane which the defender's turn describes. In the POM, the position of the attacker's nose determines the pursuit course. With the attacker's nose pointed in front of the defender (such as in the case of a gunshot), the attacker is in lead pursuit. If the attacker points behind the defender, the attacker is in lag pursuit. If the attacker points at the adversary, he is in pure pursuit. Note that an initial lead pursuit attacker could be driven into a lag pursuit course if insufficient turn rate available to maintain lead **Figure 4.3.**, Insufficient Turn Rate. Outside the defender's POM, the attacker's Lv and G determine the pursuit course.

Figure 4.2. Attack Pursuit Courses.

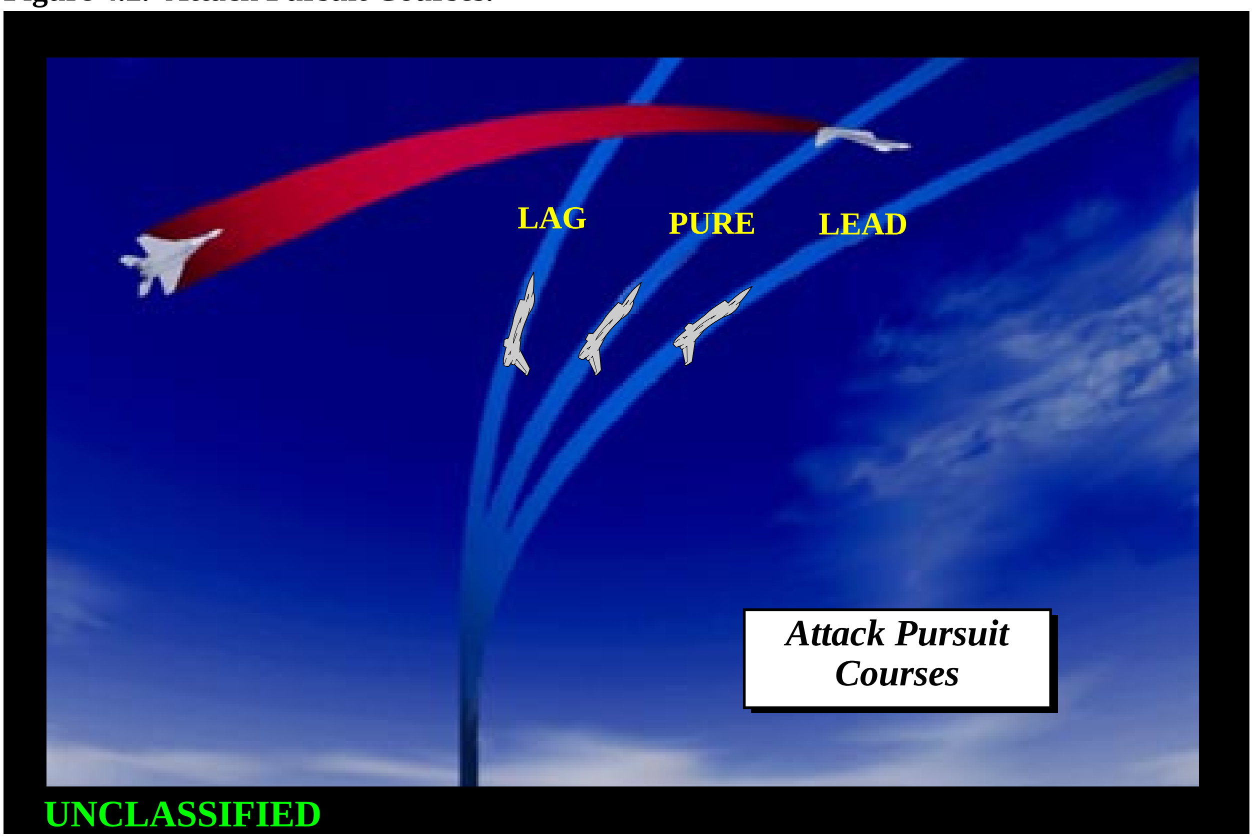
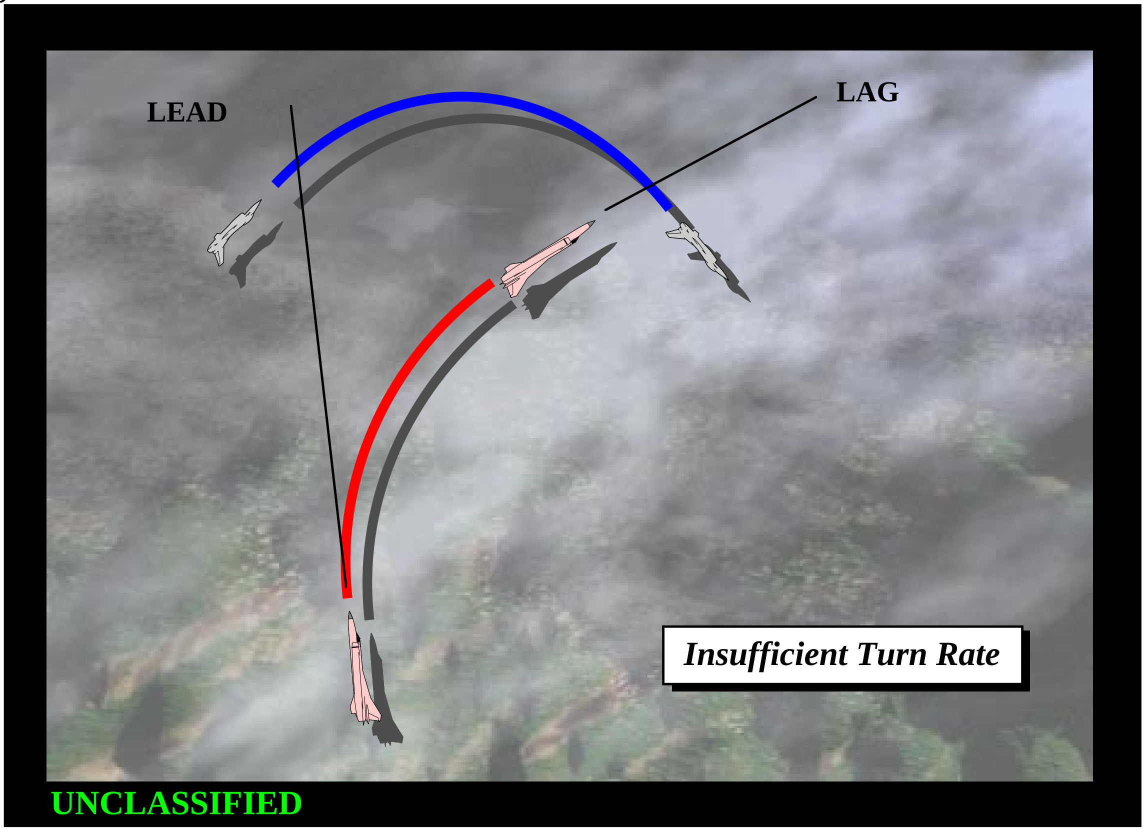


Figure 4.3. Insufficient Turn Rate.



4.3.3. Weapons Employment Zone. The WEZ of different ordnance is defined using range, aspect, ATA, and closure. BFM may be necessary to achieve a valid employment zone or to deny that area to an attacker. For realistic training, know the WEZ of your weapons and the WEZ of the enemy. During follow-on discussions, a generic fourth-generation adversary with 45 degrees off-boresight missile capability and turn and energy performance similar to a Viper will be used.

4.3.4. Turn and Energy Performance. Turn rate and radius describe the current maneuvering condition of an aircraft. See **Figure 4.4.**, EM Diagrams. Turn radius is based only on TAS and radial G. The size of the circles (radius) and the relative turn rate (how fast you can get around that circle) determine how well the pilot can solve the angular problems the defender presents. How well an aircraft can turn is a function of the turn rate and radius it generates. Radius defines the size of an aircraft's turn or its "turn circle (Tc)." In the F-16, turn radius at maximum angle of attack (AOA)/G is relatively constant between 170 and 330 KCAS. Above 330 KCAS, turn radius increases slightly as maximum G is obtained (440 KCAS). Above 440 KCAS, turn radius increases dramatically. Because of the F-16 flight control system (FLCS), the F-16 does not have a true corner velocity. It has a "corner plateau" which occurs between 330 to 440 KCAS and produces a good turn rate based on available G. Offensively, sustained operations are not possible in the same plane against a defender with a smaller Tc (radius) assuming similar turn rates without inviting an overshoot or reversal situation. A breakdown of rate and radius is shown in **Table 4.3.**, Turn Rate/Radius/P_S.

Figure 4.4. EM Diagrams.

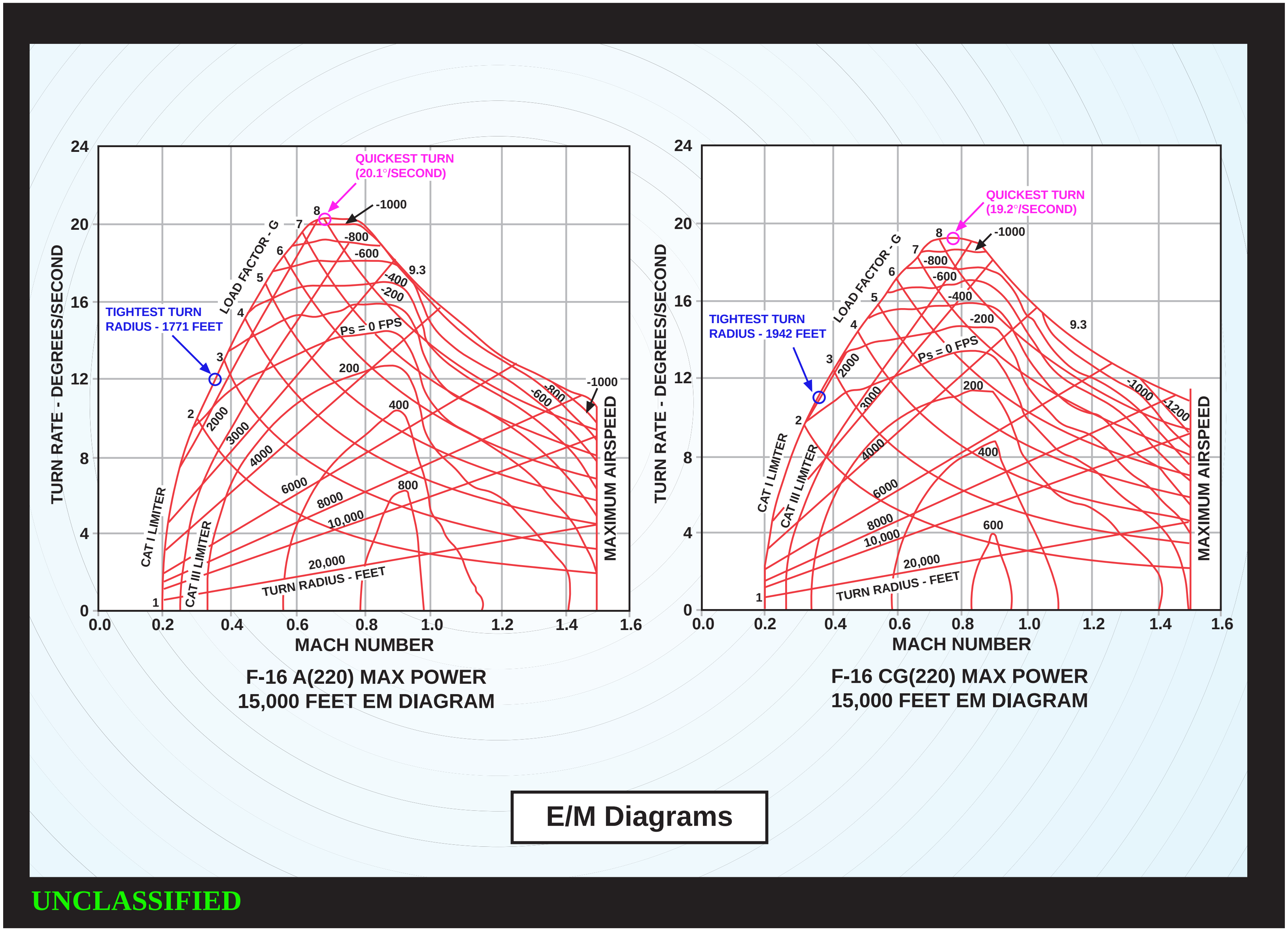


Table 4.3. Rate and Radius Formula.

Rate and Radius Formula	
TURN RADIUS	**TURN RATE**
(feet) = V2¸ (G x G_{radial})	(degrees per second) = (G_{radial} x 1092)¸ KTAS
V = KTAS x 1.69	
G = 32.2 feet per second	
G_{radial} = Cockpit G level	
NOTES:	
1. Turn rate and radius are simple functions of airspeed and G, regardless of airframe or engine. Differences lie in the ability of an aircraft to pull G and sustain energy levels.	
2. Energy definitions:	
Instantaneous rate: The highest rate an aircraft can generate at the current airspeed. This usually implies a negative P_s.	
P_s: Rate of energy loss or gain during a particular maneuver	
Sustained rate: the rate generated while maintaining current airspeed and altitude.	
Bleed rate: Similar to P_s. The amount of energy lost at a particular G level.	
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4.3.5. Gravity and Angle of Attack Effects. Gravity effects the turn performance of every aircraft. Pulling up, away from the earth causes a greater loss of airspeed and less "net" G, which increases the turn radius. Pulling toward the earth preserves some airspeed and more "net" G is produced. Another phenomenon that must be understood is how AOA effects sight pictures and drawing reconstruction. Simply put, an aircraft skids around the turn. This means the heading shown in the HUD is the direction the nose is pointing at any given instant, but is not the amount "around the Tc" when drawing. As the F-16 slows, AOA increases, making a larger difference between the nose heading and the actual position drawn in reconstruction. To illustrate this point, there are two significant points where this is important; the Tc entry and the conversion to guns. When drawing, most mistakes are made when the defender's tape is stopped at a heading and that heading is used to depict how far around the turn the defender has gone. At maximum G, above approximately 350 knots, the AOA averages 10 to 15 degrees. Below 350 knots AOA increases to approximately 25 degrees. Although degrees of AOA do not directly correlate to the difference between the HUD heading and the vector heading, they are "close enough" for reconstruction purposes. As a technique, take 10 to 15 degrees off the heading when above 350 knots and 20 to 25 degrees when below 350 knots (at maximum G loading) to depict the true position of the aircraft. The sight picture the offender sees is always higher than the radar displays. This difference is the amount of AOA the aircraft is under. At higher AOA the aircraft appears to have a higher HCA, and the offender is at a higher aspect, the true LOS though is much less as the defending aircraft is skidding through the sky. The tactical implication of this phenomenon is that the sight picture may look worse than the true HCA/AA condition. For example, a 90-degree gunshot (apparent to the eyeball) may produce only a 60-degree AA and corresponding closure rate problem.

4.3.6. Turning Room. In order to discuss how BFM can solve range, aspect, and ATA, two concepts: available turning room (Tr) and Tc, are used. Turning room is the separation between two aircraft that can be used to accelerate, decrease range, or turn and decrease AA and ATA. A Tc is determined by aerodynamics and is based on current radial G and airspeed. Turn rate is how quickly the aircraft goes around this circle. (See **Figure 4.5.,** Turn Rate/ Radius/P_s.)

4.3.6.1. Attack Geometry. As the defender bleeds off energy and airspeed during a defensive turn, the turn radius (and radius) will decrease. This relationship often results in a characteristic “fishhook” appearance to the defender's turn. The attacker may ***start*** inside the Tc, but unless exactly matching the defender's rate and changing radius (by reducing airspeed), will end up outside it. Another way to “stay inside” the turn is to use vertical to gain additional “room.” It is very important to note that turning room can be acquired in any combination of lateral or vertical planes. Also, either aircraft can use turning room. (See **Figure 4.6.,** Turn Diagrams.)

4.3.6.2. Lateral Turning Room. Lateral turning room is ***in*** the bandit's POM. The bandit's turn direction and G loading will effect how much turning room is available. If the attacker is inside the bandit's Tc (bandit has turned toward the fighter), he must have a turn rate and radius capability that will allow him to “make the corner” the bandit presents. This maneuver frequently requires high-energy bleed rates to make the corner and stay in the bandit's POM. If the bandit turns away (shows belly) even more room is available.

4.3.6.3. Out-of-Plane Turning Room. Turning room can be acquired ***out*** of the bandit's plane of turn. This is termed out-of-plane maneuvering as shown in **Figure 4.7.,** Out-of-Plane Maneuvering. If the bandit is in a vertical turn, this turning room may be located in a horizontal plane. If the bandit is in the horizontal, then turning room will be available either above or below the POM. Range and closure will govern the amount of turning room that can be generated.

Figure 4.5. Turn Rate/Radius/Ps.

Turn Rate/Radius/Ps

F-16CG Blk 42   15,000' MSL   MAX AB   Drag=0   GW=22,000   Turn Rate/Turn Radius/Energy Bleed   Rate in KCAS/Sec

KCAS/M/ TAS/ FT/sec	2G	3G	4G	5G	6G	7G	8G	9G
500/ .96/ 600/ 1014		5/12k/+12	7/8.5k/+11	9/6.6k/+5	10.5/5.5k/2	12.5/4.7k/-5	14.5/4k/-13	17/3.5k/-29
475/ .92/ 580/ 980		5.5/10k/+13	7.5/7.5k/+11	9.5/6k/+7	11/5k/+3	13/4.5k/-3	15/3.6k/-10	17.5/3.3k/-26
450/ .87/ 550/ 925		5.5/9.5k/+14	8/7k/+13	10/5.5k/+8	12/4.5k/+5	14/3.8k/-2	16/3.3k/-12	18.5/2.8k/-20
425/ .83/ 525/ 887		6/8.5k/+15	8/6.4k/+12	10.5/5k/+9	12.5/4k/+3	14.5/3.5k/-5	16.5/3.1k/-5	19/2.7k/-33
400/ .78/ 495/ 832		6.5/7.5k/+13	9/5.5k/+11	11/4.2k/+7	13.5/3.5k/0	15.5/3k/-13	17.5/2.6k/-22	19/2.5k/-44
375/ .73/ 460/ 777		7/7k/+16	9/5k/+10	11.5/3.8k/+5	14/3.3k/-3	16.5/2.8k/-17	19/2.4k/-34	
350/ .69/ 435/ 735		7/6k/+12	10/4.3k/+9	12.5/3.4k/+2	15/2.8k/-9	17.5/2.5k/-27		
325/ .64/ 435/ 735		7.5/5k/+11	10.5/3.8k/+7	13/3k/-2	16/2.5k/-17	18/2.2k/-30	(6.5g max)	
300/ .59/ 370/ 625		8.5/4.5k/+12	11.5/3.2k/+4	14.5/2.6k/-8	17/2.1k/-30			
275/ .54/ 340/ 575	5/6k/+14	9/3.8k/+9	12.5/2.7k/0	15.5/2.1k/-23				
250/ .49/ 310/ 525	6/5k/+15	10/3k/+5	13.5/2.2k/-10	16.5/1.8k/-21				
225/ .44/ 280/ 475	7/4k/+9	11/2.4k/0	13/1.8k/-10	(3.5g max)				

SIGNIFICANT POINTS ON CHART

CONSTANT TURN #'s	0 Ps	INSTANTANEOUS (W/BLEED RATE)
425 KIAS	13.5°/sec/3,700' T_R	19°/sec/2,600' T_R @-33 Knots/sec
330 KISA	12°/sec/3,200' T_R	18°/sec/2,100' T_R @-30 Knots/sec
275 KIAS	12.5°/sec/2,700' T_R	16°/sec/2,000' T_R @-23 Knots/sec

BREAK TURN (AVG. MAX G PULL FOR 6 SEC)	IDLE	MIL
Tr:	2,500'	2,500'
A/S BLEED:	425 KCAS = > 250-275	425=> 325-300
AVG. TURN RATE:	16°/sec (100°)	16°/sec (110°)

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Figure 4.6. Turn Diagrams.

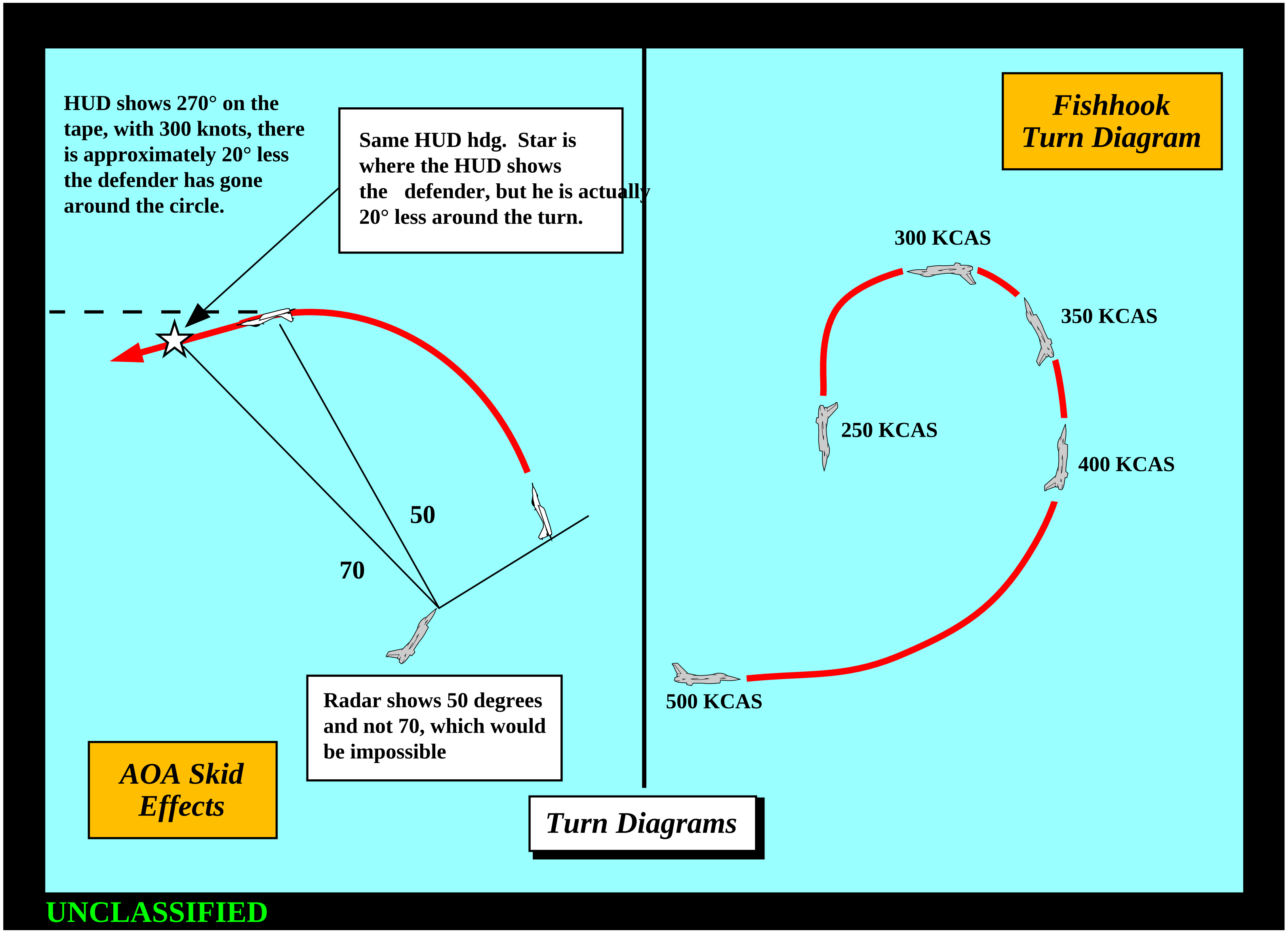
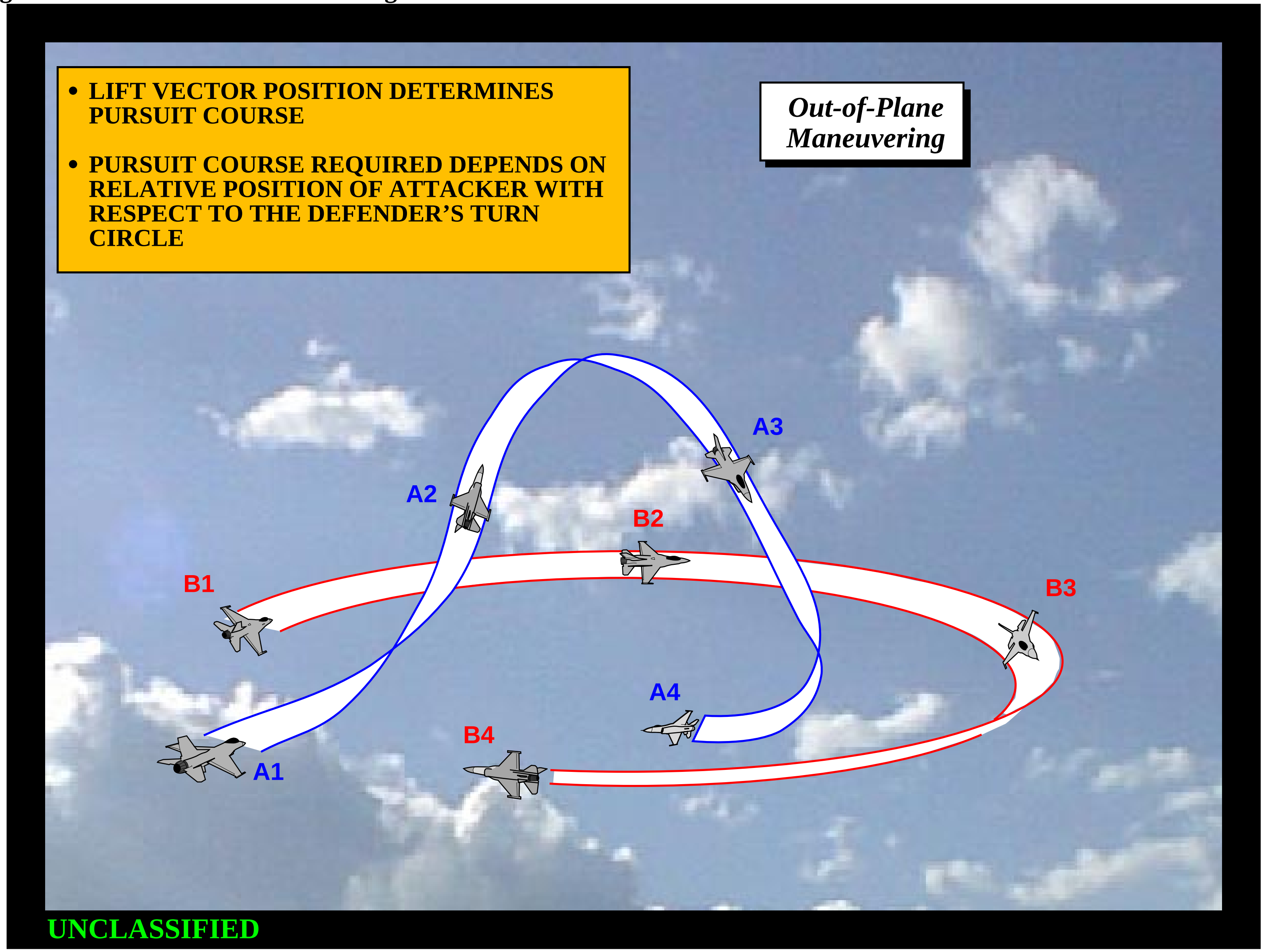


Figure 4.7. Out-of-Plane Maneuvering.

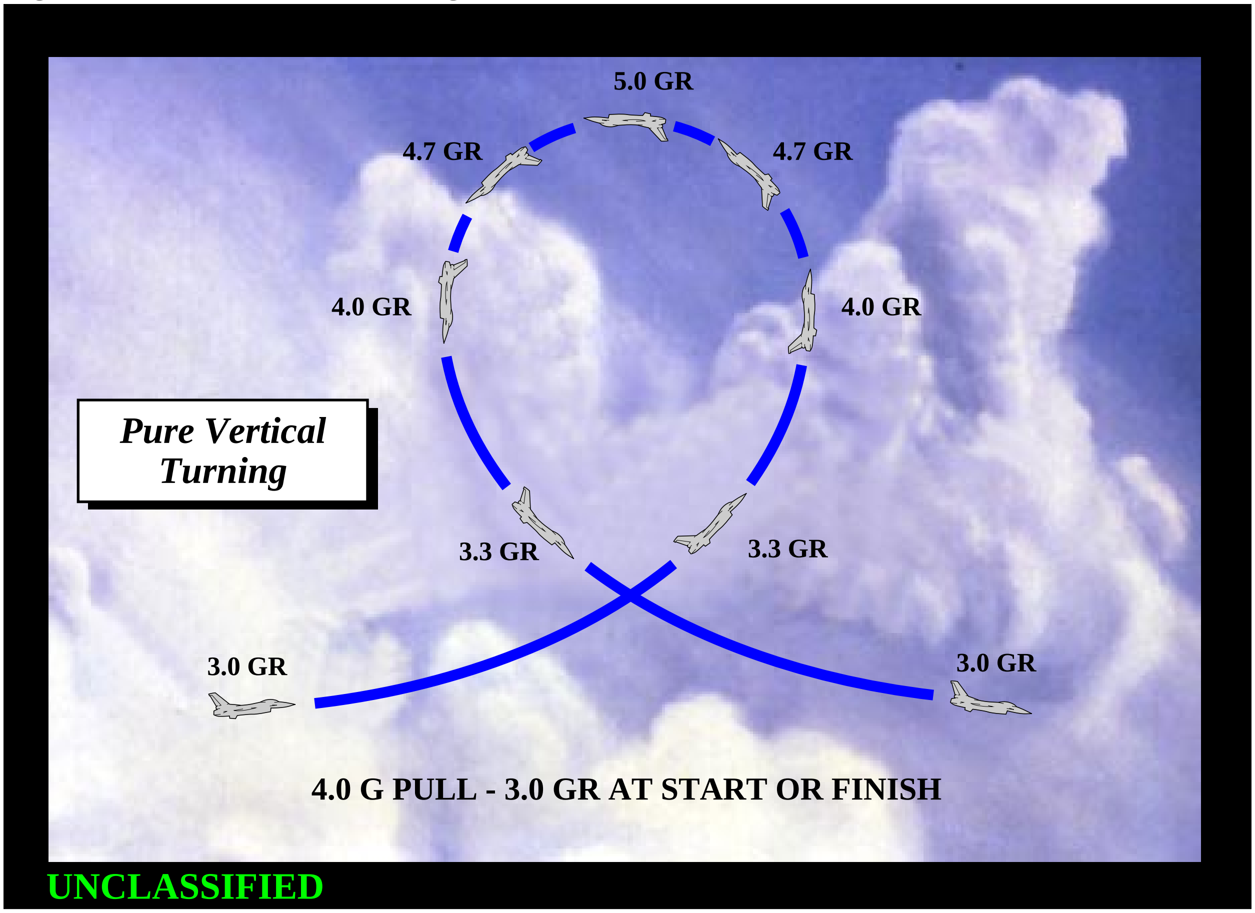


4.3.7. Roll. Roll allows the pilot to position the Lv, thus determining the POM in which to turn. At high speed and low AOA, the F-16 has a very high roll-rate capability. However, as the airspeed slows and AOA builds, the roll performance begins to degrade. At slow speed, in order to roll more rapidly, the AOA must be reduced prior to initiating the roll. It should also be noted that the slower the airspeed, the longer it takes to command a reduction of AOA. This becomes very important when maneuvering to defeat a gunshot. An important aspect of roll is the ability to slow the forward track of the aircraft. If G is maintained and a roll is initiated, a spiral flight path results, thereby increasing the "through the air" distance (and time) the aircraft flies to arrive at any selected point. An additional benefit of roll is the ability to position the bandit so the pilot can maintain a tally.

4.3.8. Using the Vertical. If a pilot can utilize a downhill turn at key points in a BFM engagement, the relative turning performance will be better than the adversary's will. This fact allows an attacker, flying proper BFM and starting from inside the defender's Tc, to maintain a positional advantage. When a vertical (downhill) turn is used, as shown in **Figure 4.8.,** Pure Vertical Turning, the apparent rate is higher with less energy bleed. The attacker can use superior turning performance to solve angle-off problems and choose the desired pursuit curve to achieve weapons employment parameters. A ***slight*** climb allows the attacker to set up the downhill part of the maneuver and reduce the distance below the defender's POM the maneuver will take. This ***slight climb to a slice*** results in a maneuver commonly called a "Hi Yo-Yo" (a "Low Yo-Yo" normally follows). Another important concept of vertical turning is "optimizing" turn rate and energy (airspeed) expenditure. Utilizing maximum available G while entering a purely vertical turn (loop) excessively bleeds energy while "working against" gravity. Generally, a lower G vertical turn is more efficient at the beginning and end of a loop, while maximum G (maximum rate) vertical turns can be best employed when working "with" gravity—from nose pointing straight up until nose pointing straight down. Flying an optimum loop—using 3 to 4 Gs at beginning and end, and maximum G available while flying over the top—maximizes vertical maneuvering potential. Maximum turn rate at the bottom of vertical turns should normally be used only to force a trailing aircraft's nose into lag and to cause the trailer to overshoot in the vertical. Vertical turns performed "pure" (i.e., no lateral or horizontal component) deny a trailing (similar) aircraft, at a lower energy state, the capability to reduce the differential by performing an oblique or horizontal turn (energy deficient bandit can not "arc" the turn). The three primary factors effecting acceleration are altitude, attitude, and airspeed.

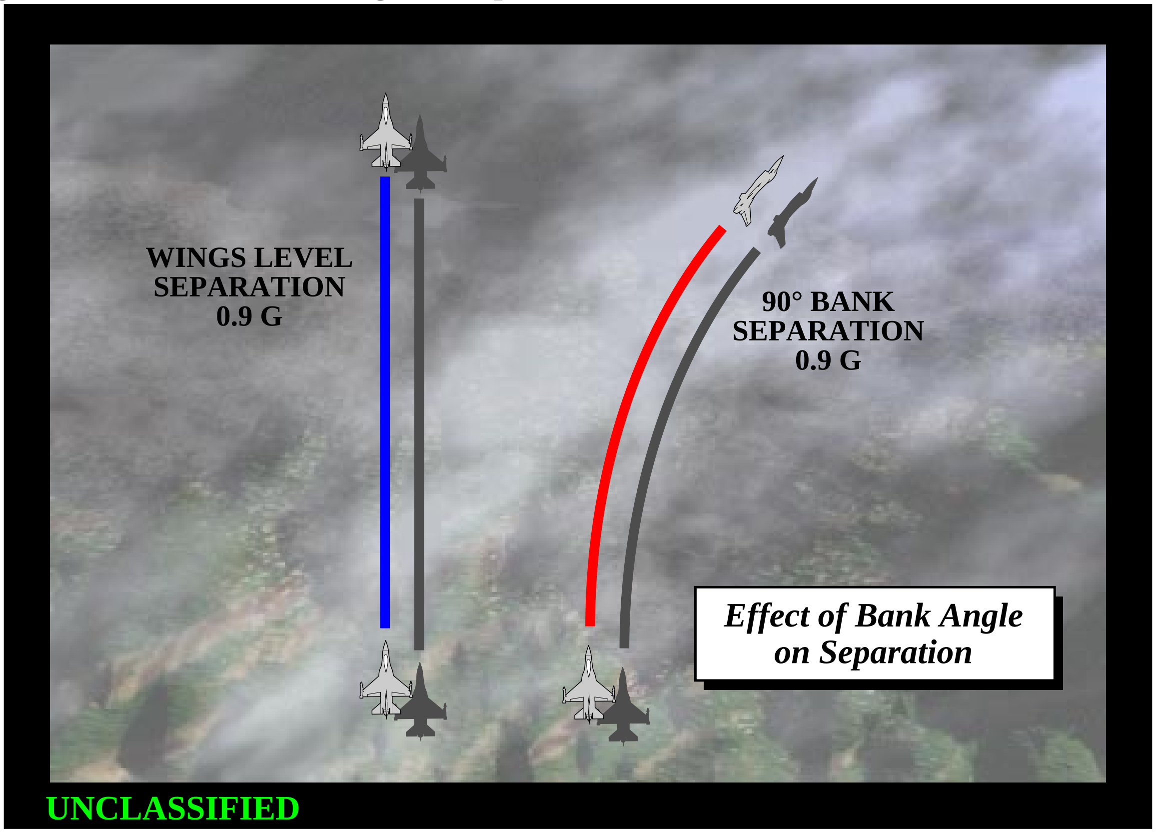
4.3.8.1. Effects of Altitude. The lower the density altitude, the more effective the acceleration will be because of increased thrust.

Figure 4.8. Pure Vertical Turning.



4.3.8.2. Effects of Attitude. The total energy gained during an acceleration maneuver is a trade off between airspeed gained and altitude lost. Aircraft attitude determines the effect of gravity on an acceleration maneuver. If the aircraft velocity vector is above the horizon, acceleration effectiveness is reduced, while potential energy increases. If the aircraft velocity vector is below the horizon, effectiveness is enhanced, but potential energy is used. Aircraft G loading effects induced drag and acceleration effectiveness. The fastest airspeed gain occurs in an unloaded (0 G), nose-low acceleration. The end result of this maneuver is a large altitude loss and very nose-low attitude that may be unacceptable in an aerial engagement. If altitude is a factor, select afterburner (AB) and fly a 0.7 to 0.9 G, slightly nose-low, wings-level extension maneuver. While airspeed gain will not be as rapid as at 0 G, altitude loss is minimized. In addition, the flight path will stay fairly constant. The point to remember is that the closer to 0 G, the faster the acceleration, the more altitude loss, and the lower the nose will end up. As bank angle increases from wings-level to 90 degrees, the corresponding "optimum" acceleration G decreases (to maintain a straight-line flight path). (See **Figure 4.9.**, Effect of Bank Angle on Separation.) At 0.9 G and 90 degrees of bank, the aircraft is turning laterally as though it was in a 30 degrees level turn. To reduce the turn effect, reduce G to 0 when approaching 90 degrees of bank.

Figure 4.9. Effect of Bank Angle on Separation.



4.3.8.3. Effects of Airspeed. Acceleration is a trade off between thrust and drag. Thrust increases at a greater rate than parasite drag as velocity increases from 100 KCAS to 450 KCAS (or 0.95 Mach whichever comes first). Above 450 KCAS, acceleration rates decrease as drag becomes dominant. As a rule of thumb, the best acceleration rates occur between 300 to 400 KCAS. Often, the purpose of an acceleration maneuver is to separate from an adversary; to get beyond maximum WEZ or gain BVR. The objective then becomes to fly a straight line over the ground to prevent the adversary from arcing. Attitude effects from **paragraph 4.3.8.2**, Effects of Altitude, gain paramount importance. The radar missile-equipped adversary can probably turn and maintain a WEZ as you flee. Separations will usually only be successful if the adversary chooses not to pursue, or cannot, because situational awareness (SA) on your position is lost.

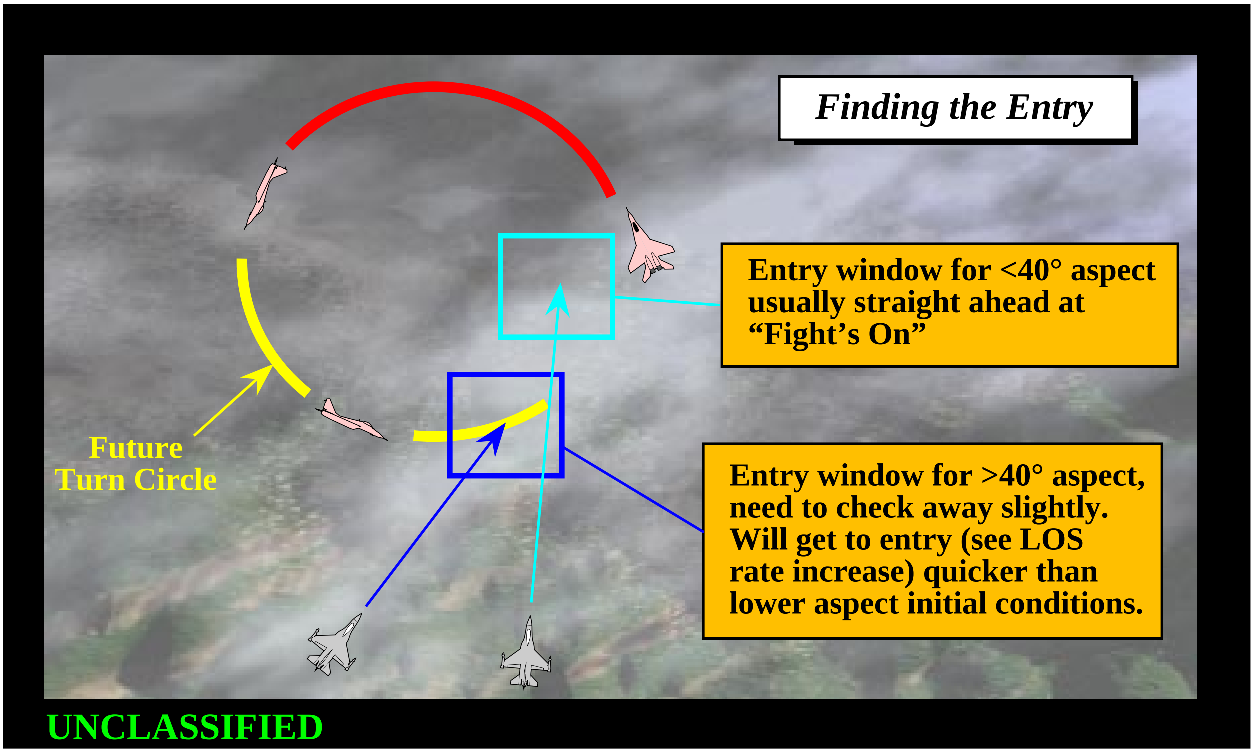
4.3.9. Offensive Basic Fighter Maneuvers. The purpose of offensive BFM is to kill the defender as quickly as possible without wasting time or gas. On every sortie try to sharpen your skills and expand your lethal envelope. This enables you to employ valid ordnance quicker than the previous sortie. A well-thought-out and executed plan is critical to build these skills. In order to prosecute a higher aspect shot, high-aspect gunshot exercises (**Chapter 9**) should be utilized to build the necessary skills in a controlled situation. These skills can later be used in the dynamic, fluid BFM fight. The thought processes in solving the offensive BFM problems are sequential in nature. With the ultimate goal of achieving a kill, one must be offensive with a WEZ; therefore achieving this state must be accomplished prior to going for the kill. Constantly assess the situation and determine if the defender is presenting an acceptable WEZ based on your ability and proficiency. When the answer to the previous question is yes, then the offender should go for the shot. If the answer is no, then the offender needs to solve the problems the defender is presenting. Ask “AM I TOO CLOSE, WITH TOO HIGH ASPECT?” If yes, continue to solve the angular problems while preserving the necessary range to stay offensive.

4.3.9.1. Objectives. The primary objectives of offensive BFM are:

- Kill.
- Stay offensive.
- Maneuver to WEZ.
- Employ valid ordnance.

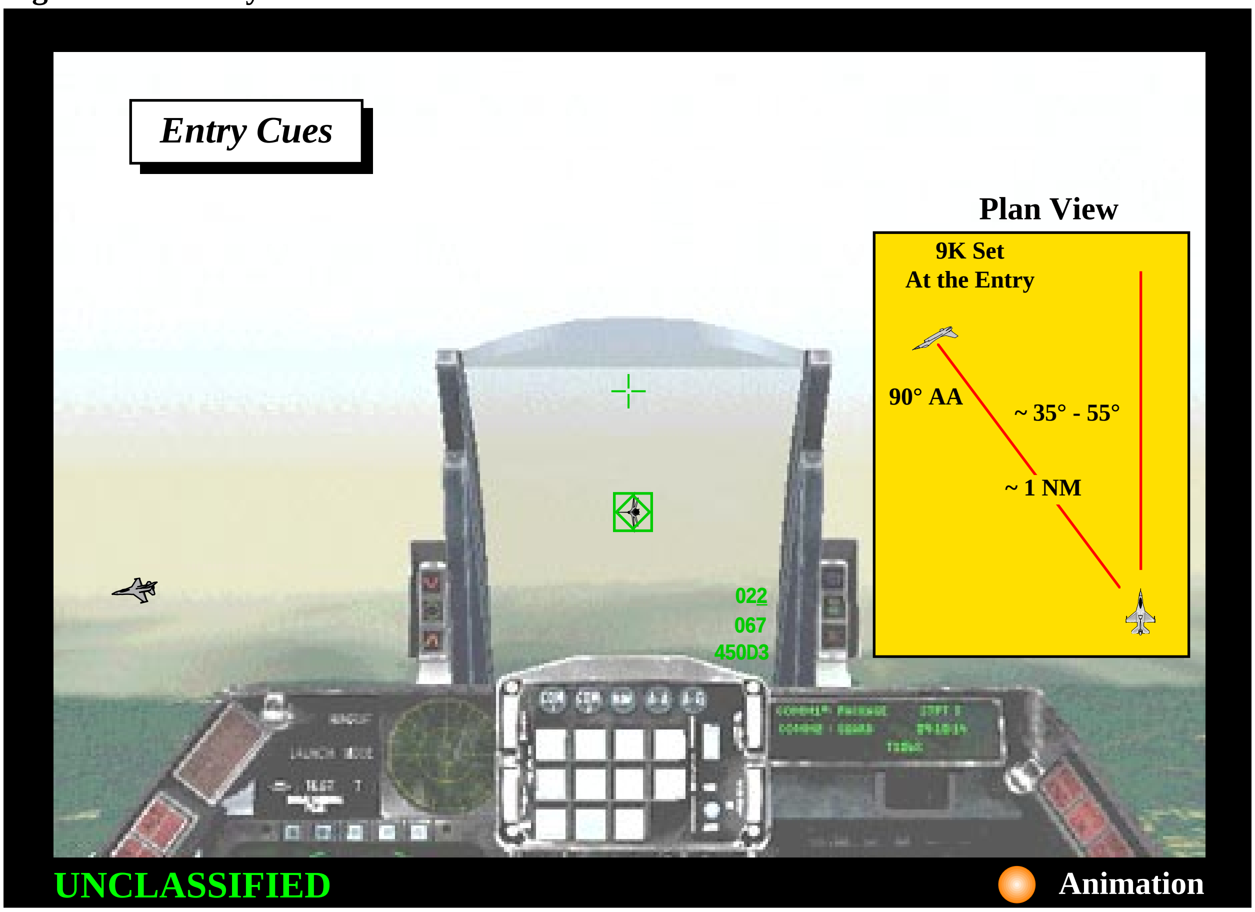
4.3.9.2. Outside the Bandit Tc. In order to prosecute a bandit, one must get to the Tc, then solve the angular and range problems presented. Typical fourth-generation fighters have maximum performance turn radii's of about 3,000 feet. This produces a 6,000-foot Tc. The first step is to recognize your position relative to the bandit's Tc. Normally you will be outside the Tc at the start of a 9,000-foot set. (See **Figure 4.10.**, Finding the Entry). This sight picture is typical of what any fourth-generation fighter will produce. It is important to recognize these sight cues, since the aircraft you are behind may not be performing a maximum performance turn. Sight cues, not range, dictate your actions.

Figure 4.10. Finding the Entry.



4.3.9.3. Recognition Cues. You are outside of the bandit's Tc if there is more bandit rotation than transitional movement from the bandit's aircraft. (See **Figure 4.11.**, Entry Cues.) The defender is still able to turn and increase AA regardless of your maneuvers. The defender appears to rotate in space with very little line of sight (LOS) movement across the horizon. If outside the Tc, the first task is to employ ordnance while maneuvering to maintain the offense. If the shot is unsuccessful, be ready to seek another WEZ; maybe with 20MM.

Figure 4.11. Entry Cues.



4.3.9.4. Entry Execution. The steps in getting to the Tc are critical to maintain offensive advantage.

4.3.9.4.1. *Step 1*. The offender must first point the lag entry window. A desired entry window is a spot just inside the starting position of the defender. If the attacker starts the fight from 30 degrees AA, start by pointing at the bandit and fly to where he was. Distant terrain, clouds, or flares dispensed at the start are other cues to reference. ***CAUTION***: 10 degrees heading difference equals 1,000 feet of lateral turning room difference at the entry. This error may be too much to overcome and emphasizes how critical the initial entry is.

4.3.9.4.2. *Step 2*. Get to Tc as quickly as possible, while maintaining a controllable airspeed (450 to 480 KCAS). (See **Figure 4.12.**, Entry Airspeed Effects.)

Figure 4.12. Entry Airspeed Effects.

Entry Airspeed Effects

Airspeed difference/turn of adversary/turn circle effects *

A/S	TIME TO GET TO T_C ENTRY POINT	TURN DEFENDER MAKES @ 15°/SEC
420C	7.5 seconds	112.5°
480C	6.75 seconds	101.25°
510C	6.4 seconds	96°

The difference between 420 and 480 is only 11° more that the defender generates, and 5° from 480-to-510. The slight advantage gained by the faster airspeed may not be as overall effective if the pilot needs to make drastic power modulations once reaching the turn circle entry window.

*** 9K set vs. F-16 Break turn**

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4.3.9.4.2.1. Accelerate in AB until 450 to 480 KCAS. Start a slight climb if fast (480+) to gain a 500 to 1,000 feet advantage above the bandit (about a "can" length).

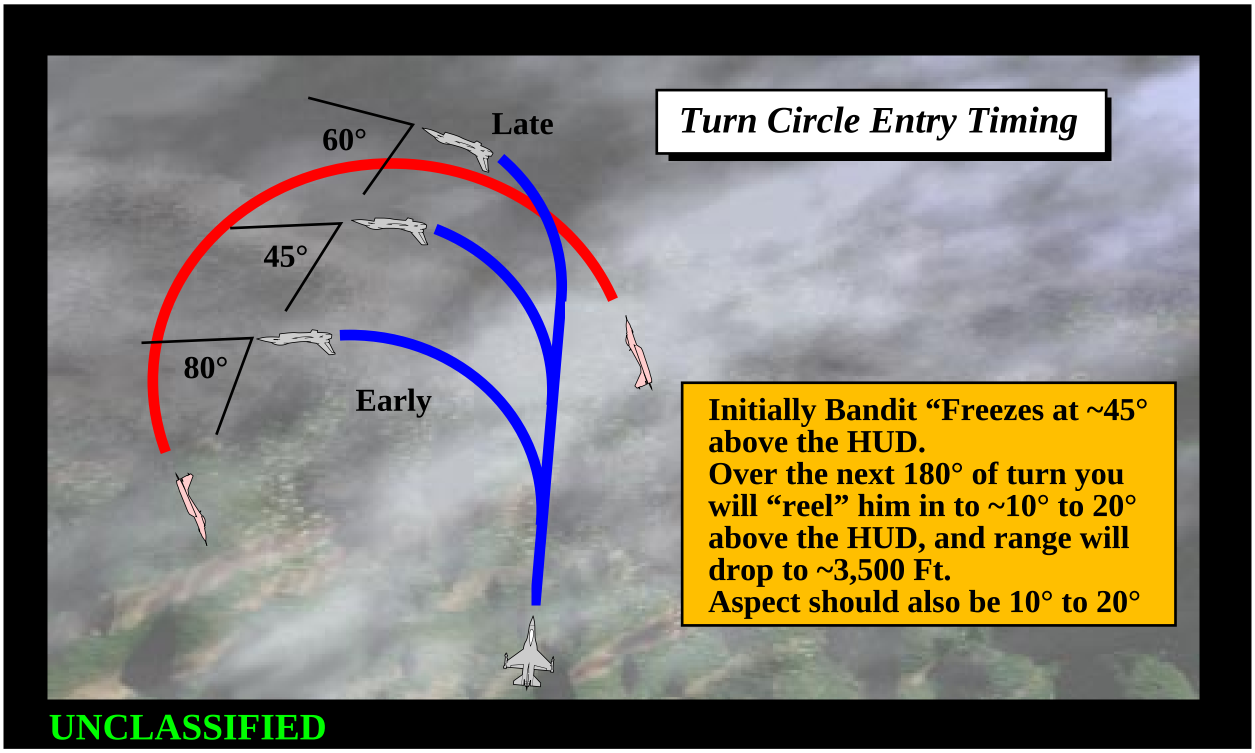
4.3.9.4.2.2. Unloading will aid acceleration, but make proper Lv positioning at the entry more difficult. The theory of "least-moving parts" is the simplest plan. A level to slightly climbing ingress will produce a good starting position with the least amount of precise maneuvering.

4.3.9.4.3. *The Left Out Step*. The most often left out aspect of the entry is the lack of missile shots. Although the emphasis is on follow-on BFM, hopefully the ordnance employed at the start will kill the bandit. Until proficiency allows, missile shots may take a lower priority in initial BFM training to ensure the mechanics are executed and understood. Recognize off-boresight shot opportunities and take them (do not let BFM suffer by continuing to pure pursuit the defender). AIM-9: check the desired launch zone (DLZ), tones, and track (if able to correlate the missile diamond to the radar track). AIM-120: just check the DLZ. In case the shots are defeated, or you are unable to employ ordnance, the need to follow-up (with BFM) is a critical skill.

4.3.9.4.4. *Step 3*. Tc arrival recognition is the next step in offensive BFM. As the bandit's rotation changes to transitional movement you have entered the Tc. LOS rate will increase and start moving aft rapidly. From a 9,000-foot set this will occur when the defender is at either the 10 or 2 o'clock position. Other cues include feeling the need to actively move your head to maintain sight; 6 to 7 seconds delay from a 9,000-foot start; or approximately 35 to 50 degrees on the locator line and 1 NM.

4.3.9.5. Tc Entry. Timing your turn to coincide with the actual entry of the bandit's Tc is essential to efficient offensive BFM. (See **Figure 4.13.**, Turn Circle Entry Timing.)

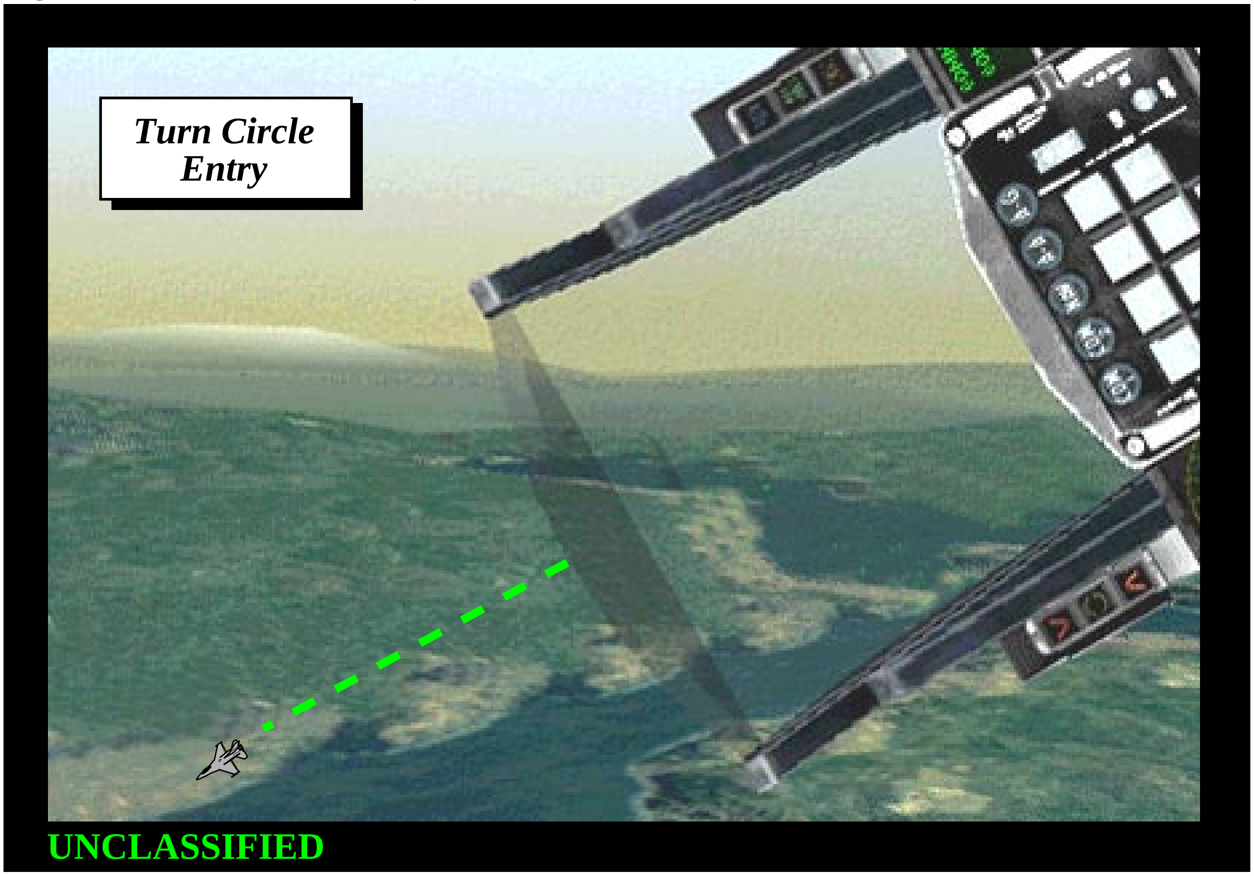
Figure 4.13. Turn Circle Entry Timing.



4.3.9.5.1. Assess the Bandit's Reaction. An F-16 performing a maximum G break and converting to a continuous turn defense should give 5,000 to 6,000 feet of range and approximately 80 to 110 degrees of aspect at the Tc entry point. A limiter defense will show less range and slightly more aspect. A weaker-G break turn will show more range and less aspect. A large vertical break will show more than ±1,000 feet of vertical difference and require a change to the flight path prior to entering the Tc. (See **Figure 4.14.**, Turn Circle Entry.)

4.3.9.5.2. Solving Initial Problems. Use an unloaded roll to set your Lv slightly above the adversaries POM, light the AB, and pull (typically 6 to 8 Gs) to start solving the angular problems. The turn is not mechanical, but a pull to solve the given problem while maintaining range. If the range decreases to less than 4,000 feet then back off on the pull and allow bandit aft LOS (unless transitioning to a lead-pursuit gunshot or missile shot). The range decrease is caused by either the attacker pulling too hard or the adversary continuing an instantaneous rate turn (decreasing the Tc). The lighter-G pull is a good initial reaction to a range problem, and will allow the offender to analyze the bandit from a stable position. At this point analyze the bandit and determine the defense: continuous turn, break and extend, limiter break, or reversing.

Figure 4.14. Turn Circle Entry.



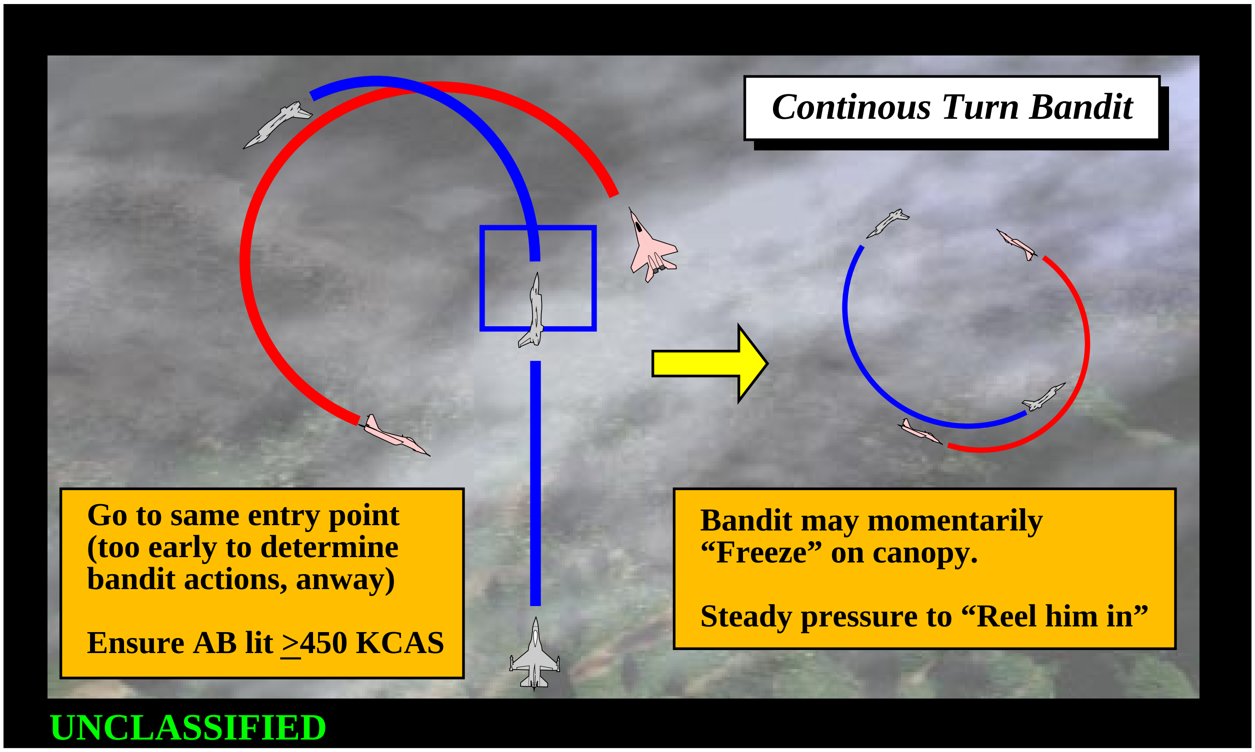
4.3.9.5.3. Continuous Turn Bandit. As shown in **Figure 4.15.**, Continuous Turn Bandit, the bandit has selected to maintain the best rate turn to conserve energy for follow-on maneuvering. In order to accomplish this, the bandit must relax the G, and reset from maximum instantaneous rate to sustained rate. The bandit's Tc will grow during this reset unless utilizing large amounts of "vertical" energy.

4.3.9.5.3.1. Recognition Cues. After the "picture" has stabilized, the cues are:

- Aspect fairly constant.
- Offender continues pull to control range.

4.3.9.5.3.2. Maneuvering. First, pull to control range (4,000 to 6,000 feet) and ATA (10 to 60 degrees). Preserve some vertical turning room high (500 to 1,000 feet) for later use to convert to lead pursuit. Maintain airspeed 325 to 375 knots (optimizes rate, preserves energy so instantaneous rate is available later) or 50 knots above defender speed. Use sustained ***rate*** to solve aspect problems. Bandit aspect and HCA slowly decreases. Range may decrease as this happens. Relax the G if range is too close (less than 4,000 feet) unless transitioning to a WEZ. This series of hard pulls/slight let-offs in G should solve the range and angular problems until a WEZ is recognized. Transition to a gunshot (typically lower aspect) at this point (covered in **paragraph 4.6**, Gun Employment).

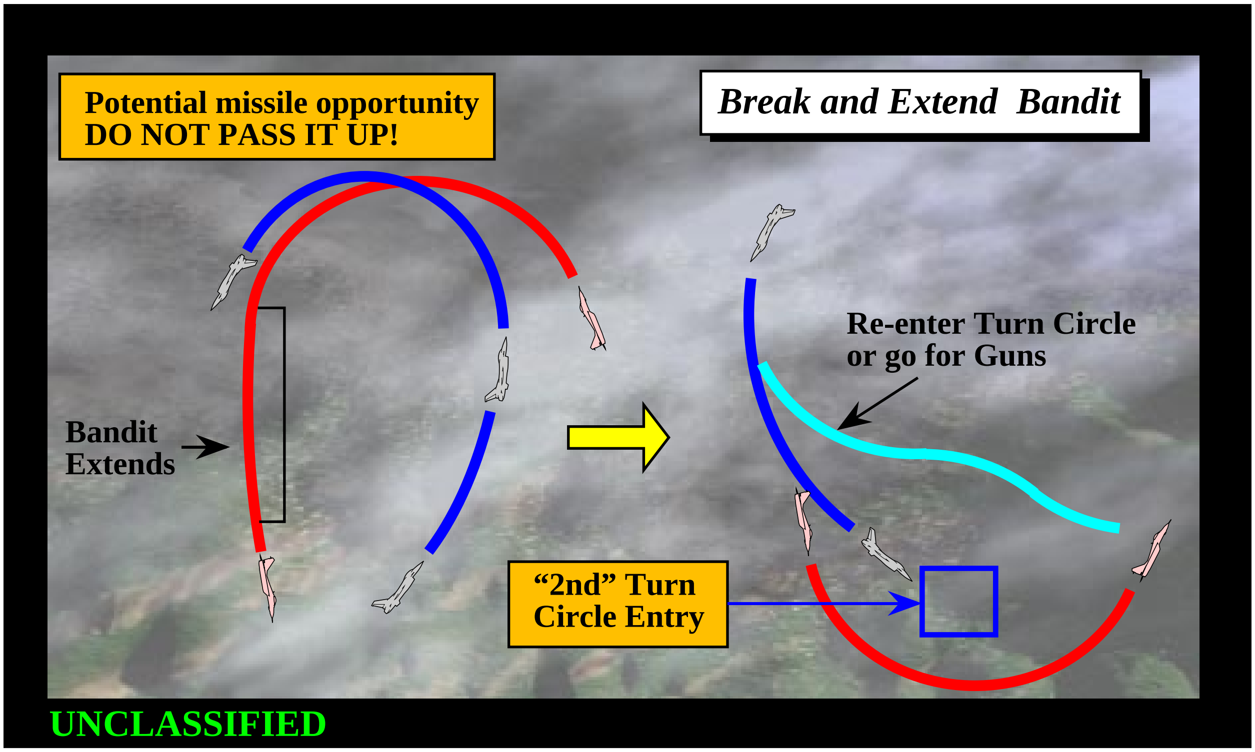
Figure 4.15. Continuous Turn Bandit.



4.3.9.5.3.3. Bandit Maintains Rate. If the problem does not solve itself using sustained rate, then a change in game plan is in order. The best tool to create a rate or energy advantage is to threaten the defender utilizing superior vertical and/or instantaneous rate. If the picture stabilizes during a sustained rate fight (AA not being solved), pull hard to achieve a heater WEZ. The defender will have to react with a power reduction and/or break turn. If not, the missile should destroy the adversary at this point. If too tight to threaten with a missile, allow the range to increase by relaxing G (offset Tc slightly), and then threaten. Execution: Pull to threaten, power in AB, employ ordnance, and then reposition back to the "elbow" when the bandit reacts. This should drive the bandit off the "best" rate and give the offender a rate advantage and the ability to solve the range and angular problems. It is important to realize that this move is just enough to force a defender's power reduction and break/jink, yet allow a quick reposition. Monitor HCA and turning room, do not overshoot. Let the defender slide no more than 1 to 2 o'clock positions away from the nose (a HUD diameter), and be ready to put the pressure back on immediately. A Low Yo-Yo may be the next move to get pressure on quickly. Remember, stay on the 0 P_s curve, and maintain an energy advantage (rate advantage).

4.3.9.5.4. Break and Extend Bandit. This type of bandit initially reacts with an effective break turn, but then relaxes G to gain/regain energy or separate as shown in **Figure 4.16.**, Break and Extend Bandit.

Figure 4.16. Break and Extend Bandit.

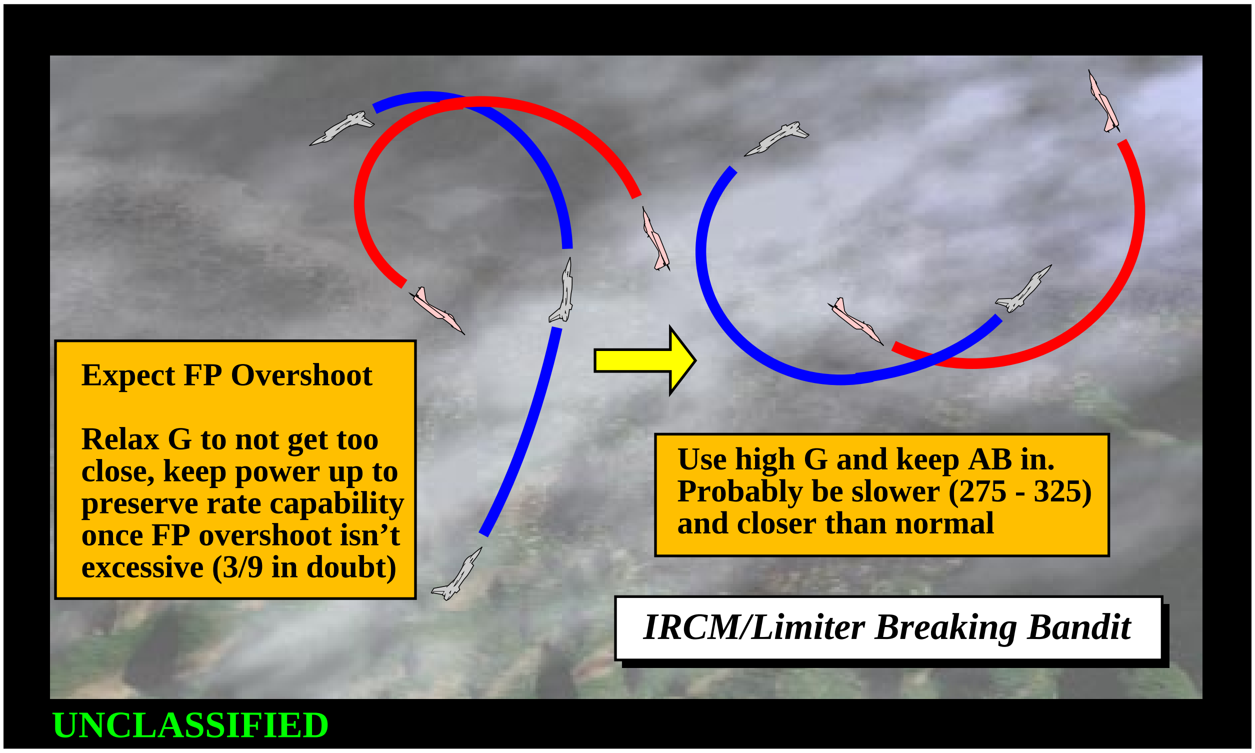


4.3.9.5.4.1. Recognition Cues. The picture never stabilizes. The range remains fairly constant or increases while aspect rapidly decreases. Offender starts seeing more tail pipe and less aircraft planform.

4.3.9.5.4.2. Maneuvering. Continue to pull aggressively, maximum G, and look for a missile WEZ. Use the ACM modes of the radar to regain the lock (if required). Initially use 10x60, but if not already locked as the target enters the HUD, use boresight. Select the appropriate missile, confirm clear avenue of fire (CAF), and shoot. Analyze bandit's reaction and select a pursuit curve. Keep in mind, the extension has increased the bandit's energy state. The bandit can re-break aggressively and ruin an immediate gunshot attempt. The best option may be to re-enter the bandit's Tc (i.e., not a transition to the guns picture). It is important to re-establish the Tc entry cues and sight pictures, but the timing/locator line/range cues may be different. As the offender does this, the missile in-flight should destroy the bandit. Remember, LOS rate increase is the key. Another option is to immediately pursue a high-aspect gunshot (covered in **paragraph 4.6**, Gun Employment). Keep in mind that maneuvers which complicate follow-on BFM may be "putting all your eggs in one basket." If you get a successful shot and the defender is taken out of the fight, you have solved the problem. If the defender survives, either through skill, cunning, or luck, the problem may now be unsolvable.

4.3.9.5.5. Infrared Countermeasures (IRCM)/Limiter Break Bandit. This type of bandit continues the maximum instantaneous rate turn until minimum airspeed. This bandit usually combines a vertical—down maneuver with the break as shown in **Figure 4.17.**, IRCM Limiter Breaking Bandit.

Figure 4.17. IRCM Limiter Breaking Bandit.

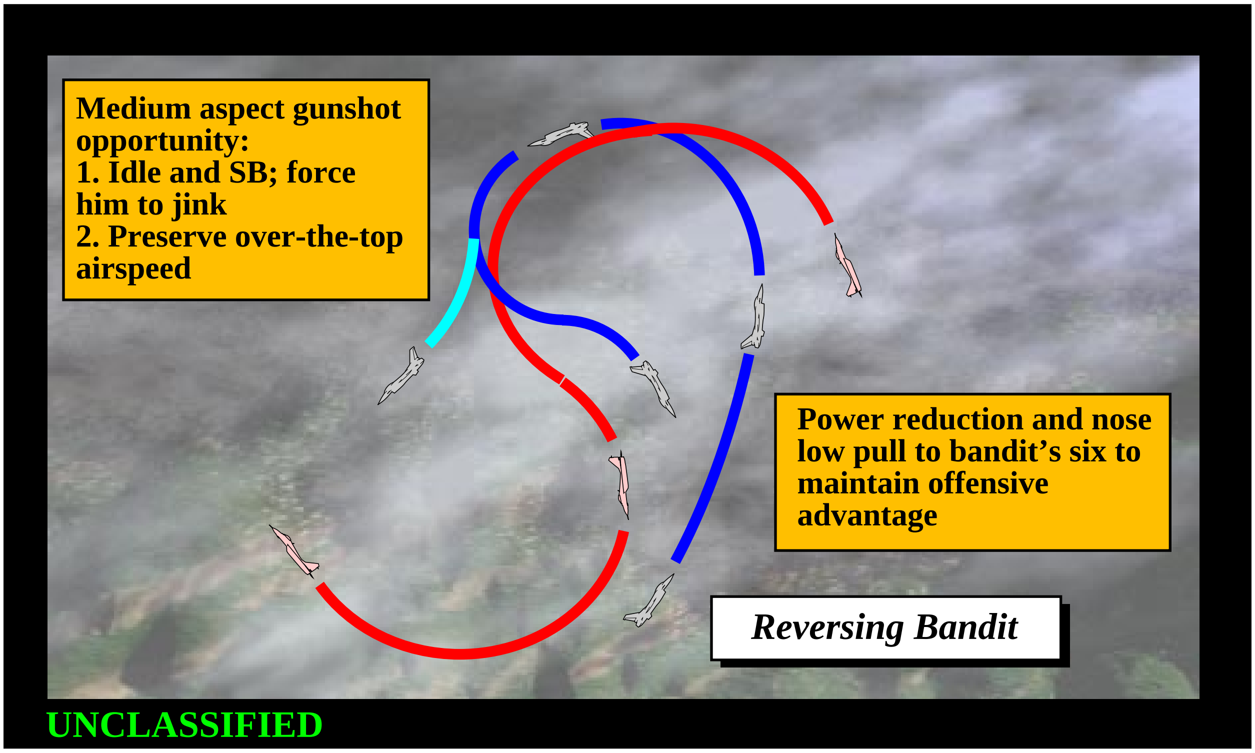


4.3.9.5.5.1. Recognition. Similar to the continuous turn bandit, except that the range at stabilization is less and there is a high potential for a flight path overshoot.

4.3.9.5.5.2. Maneuvering. Continue the pull to generate the turn rate to solve the angular problem you are facing. If only HUD cues were used for the Tc entry, expect a flight path overshoot. Ensure LOS rate cues are present before "entering." The defenders maneuver results in much less airspeed, which limits maneuvering options: continuing the break turn below optimum corner airspeed results in high energy bleed rates (negative specific power [P_s]). The turn rate of the defender decreases allowing the offender to solve the angular problems, but the defender is at minimum radius. The defender may elect to use the available altitude to help preserve airspeed and turn rate. As the offender, continually assess range (it is the big problem) and let up momentarily on G (preserving range) as you solve the angular problem. Keep the power up (AB) and initially match the defender's rate. A low aspect, at-the-floor gun or missile shot is probably the likely result from a defender staying on the limiter and descending to keep airspeed (rate) up. The defender should be at the floor relatively quickly. As the offender, match the defender in the vertical (plus 500 to 1,500 feet) while the defender spirals down, to optimize rate.

4.3.9.6. Bandit Reverses at Tc Entry. This bandit reverses turn during the initial Tc entry (while the offender is stabilizing the picture). (See **Figure 4.18.**, Reversing Defender.) This nose-counter type of defense is trying to capitalize on a perceived overshoot. For correct Tc entries, a reversing bandit is offering the offender a simple solution to the BFM problem. If the offender has made an error on the entry the defender is attempting to exploit it. The solution to the defender's error of an untimely reversal is relatively simple, but the offender must be ready for it—surprise is sometimes a very effective weapon in BFM.

Figure 4.18. Reversing Defender.



4.3.9.6.1. Maneuvering. The offender has several options against a reversing bandit. If the offender is in a desirable and controllable WEZ, an immediate transition to guns is the correct maneuver. If not, a bid to lag to preserve the offensive potential is the correct move. If the defender is making a move to put 3/9 position in doubt (incorrect Tc entry) two options to ensure the offensive exist: threaten or quarter-plane. Execution basics include:

4.3.9.6.2. Transition to guns; pull power, setup for the gunshot and prosecute the attack.

4.3.9.6.3. Bid to lag; modulate power to control the size of the turn, maximum pull with Lv low, pull to elbow, be ready to repeat if defender reverses again.

4.3.9.6.4. If the 3/9 line is in doubt:

4.3.9.6.4.1. Power in AB, intimidate with gun and missile, and preserve over the top (OTT) airspeed.

4.3.9.6.4.2. Quarter-plane with idle/speedbrakes etc.

4.3.9.7. Gun Employment. At some point during the engagement, the gun will become the weapon of choice. This may be due to missile failure or depletion, WEZ exclusivity (too tight), or bandit maneuver potential (cannot get away). There is no minimum range for the gun, but consider bandit frag patterns and the single engine FOD problem after the shot.

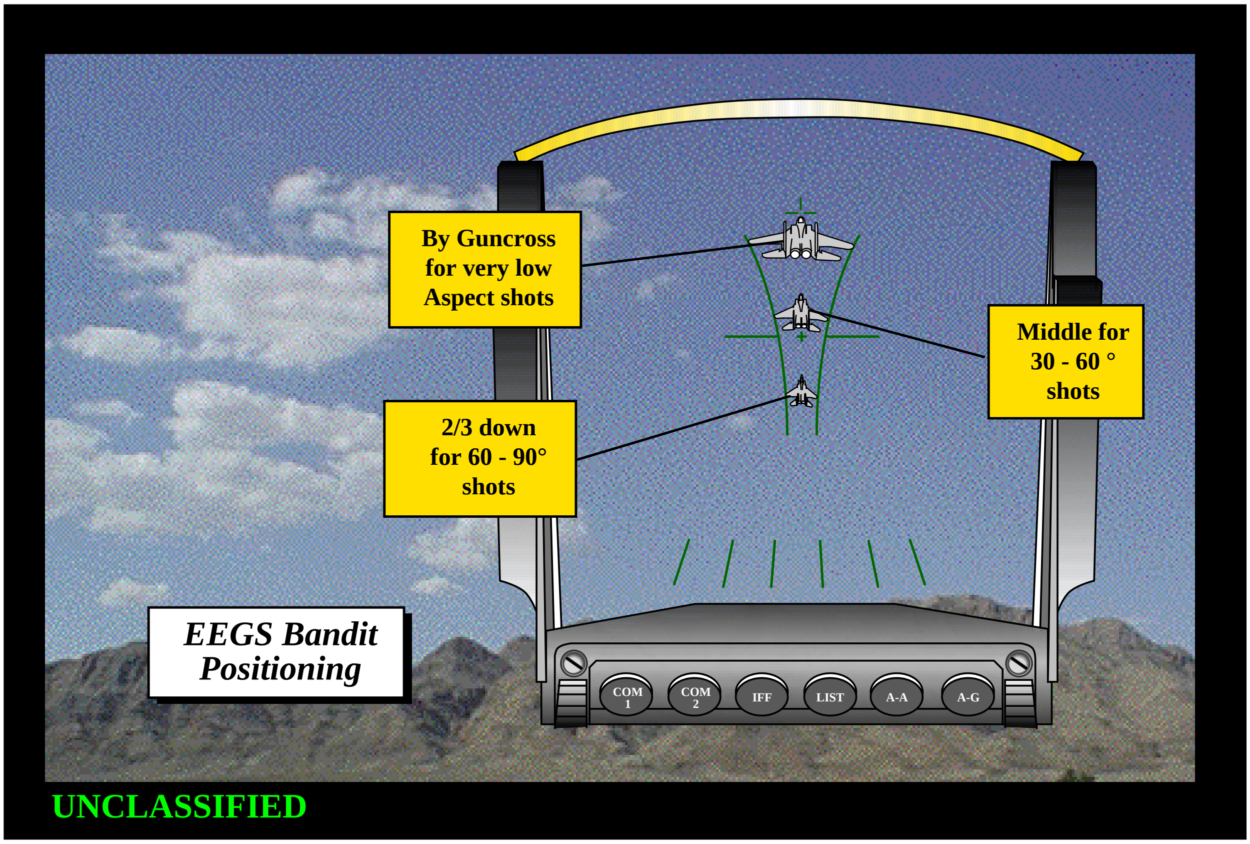
4.3.9.7.1. High-Aspect Gunshots. For shots well within the bandit's Tc (higher aspect) the offender must consider follow-on maneuvering if the shot is defeated. If airspeed allows use of the vertical (up) after the shot, it may be the place to go. Otherwise, protect against an overshoot and 3/9 line exchange if the bandit does not react and the shot is unsuccessful. This gunshot attempt, even if unsuccessful may force the bandit to react (jink) allowing an immediate transition to low aspect gun employment. This reaction may dictate the high aspect attempt.

4.3.9.7.1.1. Transition from BFM. Aspect will increase based on the turn rate the defender can generate during the conversion to guns. As a ROT expect 20 to 40 degrees higher aspect than initially seen. If comfortable with that aspect and the corresponding range, then continue in for the shot. If not, then solve more of the aspect before maneuvering for the shot. High-speed defenders can maneuver well out-of-plane and also significantly increase aspect during the high-aspect shot. With a continuous turn defender, the bandit holds airspeed in reserve (instantaneous rate) and the offender may not be able to immediately transition to gun employment successfully. Defenders with only large radius and low rate options are usually better targets for high-aspect employment. General Mechanics for the transition (whip around):

- Lv low, in lead. Maximum G to get around in minimum time.
- Reduce power, speedbrakes out once lead is achieved.
- Gain a radar lock. 10x60, boresight if required with bandit in HUD.
- Missile shots until in gun range.
- Put the bandit two-thirds down the HUD with gun cross in lead.
- Employ the gun (see **paragraph 4.6,** Gun Employment, for gun sight specifics).

4.3.9.7.1.2. Repositions/Jinking Bandit. If the bandit is aware of your high AA, expect defensive maneuvering. If the bandit maneuvers, decide to reposition early and maneuver aggressively. Proficient high-aspect shooters can probably continue the attack until about 2,000 feet before repositioning. (See **Figure 4.19.,** EEGS Bandit Positioning.) Limited proficiency shooters should err conservatively and reposition between 3,000 and 4,000 feet. The earlier the offender comes off, the sooner the defender can put the Lv back on, and continue to cause aspect problems. The longer the offender can press the attack the longer the defender needs to jink. This typically gives the offender the turning room to continue the attack from an offensive, low-aspect position.

Figure 4.19. EEGS Bandit Positioning.



4.3.9.7.1.3. Reposition Mechanics. Repositions from a high-aspect opportunity are often misunderstood and misapplied. Think of the reposition from a high-aspect gunshot in terms of a "bump and slide" while pulling power and extending the speedbrakes. The offender's goal is to arrive at the defender's elbow, essentially within one clock position aft of the defender and one clock position off the offender's nose. Let the defender slide one to two clock positions from the HUD, and then pull to "square the corner" to decrease HCA and AA.

4.3.9.7.2. Low-Aspect Gunshot. This gunshot allows the offender to easily maintain the offensive advantage while employing the gun in a track-shoot-track flow. Normally the bandit is at a relatively low energy state and the offender's primary concern is to preserve range while employing the gun.

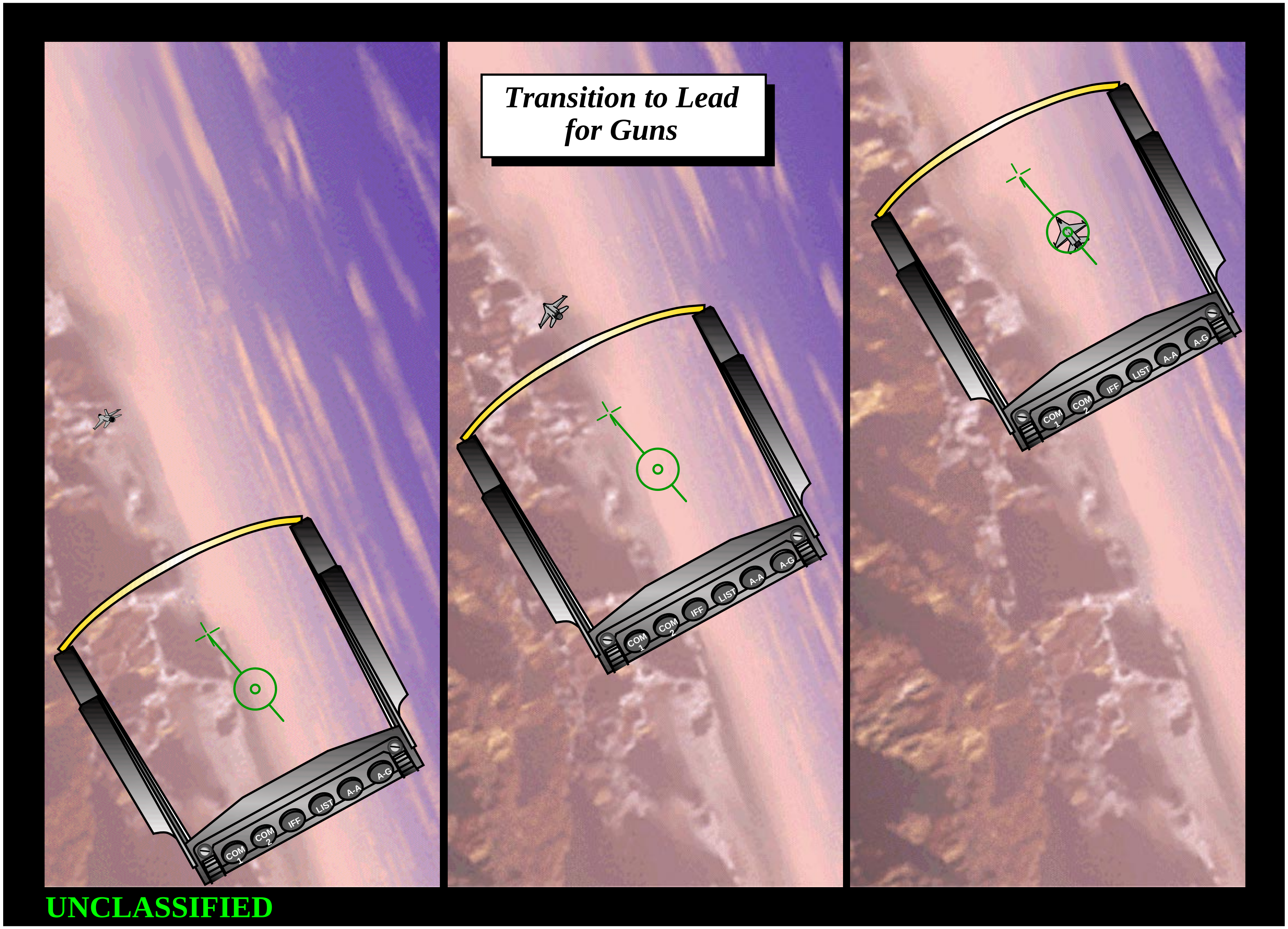
4.3.9.7.2.1. Transition to Low Aspect Guns: Once the aspect and range is determined and acceptable, a transition to lead pursuit to use the gun is the next step. (See **Figure 4.20.**, Transition to Lead for Guns.) As lead is established, reduce power to idle and extend speedbrakes. This transition is normally in-plane—vertical maneuvering (Low Yo-Yo) is not required. If slewable or 10x60 do not lock the bandit, boresight is available as the bandit is pulled into the HUD. Do not delay the shot while waiting for the radar to lock. There is no need to pull excess lead (more than half way down in the HUD); it allows the defender more time to generate angles. Initially aim with the gun cross; put it in the defender's POM and once the proper rough lead and plane are established, finesse the final solution by using the director "pipper." Place the pipper on the defender's aircraft and fire a lethal burst of 1 to 2 seconds. Reposition and prepare to re-establish the gunshot if the defender is not destroyed. (See **Paragraph 4.6.5.4**, EEGS, for specifics.)

4.3.9.7.2.2. Reactions and Repositions. The defender may react to your gunshot attempt and you must be ready.

4.3.9.7.2.2.1. Defender In-Plane Reactions. The uninitiated defender will pull hard, Lv on, simply giving you a slightly higher aspect problem, which is easily solved with a lethal burst. Adjust lead, keep the pipper on, and fire. The other option is for the defender to unload and show approximately 0 degrees aspect. Although this will significantly disrupt the gun solution, a solid missile WEZ should be available.

4.3.9.7.2.2.2. Defender Out-of-Plane Reactions. A smart defender will attempt to spoil your shot through a change in plane. A defender can make a rolling maneuver or an out-of-plane jink. As the offender, assess the maneuver, and either continue to shoot, or wait for the defender to finish the jink and setup the shot as the defender comes out of the jink. Do not attempt to track if the maneuver is aggressive enough, (at roll rates of 10 degrees per second the pipper will lag the true solution anyway). Instead, setup the shot as the defender comes out of the jink. As a ROT, never let the closure rate get higher than 5 percent of your range (i.e., 150 knots closing velocity (V_c) at 3,000 feet, 100 knots at 2,000 feet, and 50 knots at 1,000 feet) unless you are committed to your last shot and will accept an overshoot. If closure is under control, predict where the defender will come out of the jink and have the gun cross in lead, in that POM, and fire a lethal burst with the pipper on the aircraft. If closure is not under control or range is too short (1,000 to 2,000 feet is a comfortable, lethal range) use the jink as an opportunity to decrease V_c or increase range. As the defender jinks, make a bigger similar maneuver, but do not let the defender get too far away from the nose (one clock position—no more than 25 degrees on locator line, or one HUD diameter). Repeat the whole process over until a kill is achieved or you can no longer stay in the offensive position.

Figure 4.20. Transition to Lead for Guns.



4.3.9.8. Follow-on to Gun Employment. When it becomes apparent that you will no longer stay in your desired shoot window it is time to maneuver to maintain a 3/9 advantage. A quarter-plane maneuver to the bandit's high 6 O'clock to maintain 3/9 is normally required. This maneuver should only be sufficient to increase range to then reapply pressure for another gun attack. A normal error is to maneuver too far out-of-plane and allow the bandit to build too much aspect. Although a slight flight path overshoot will not allow a bandit reversal, use enough vertical to stay inside the bandit extended centerline. If started early, only a slight out-of-plane maneuver is required, and the bandit should remain within 25 degrees of the HUD. If late, a larger reposition is required. Minimize your flight path overshoot with the vertical pull to six. AB is required during the reposition to maintain a rate advantage. Select AB as you take the final shot. If the bandit has sufficient airspeed expect him to try to transition to either a scissors or a stack. (See **paragraph 4.3.10.5.8**, Reversal Follow-Ons.)

4.3.9.9. Vertical Fight—Offensive. The defenders use of the vertical resets the fight in a different plane. This has some distinct differences from a "normal-descending fight." First, the defender can maintain a high turn rate. Second, this attempt go over the top, or use excessive vertical, may be to exploit airframe capability or confuse the offender. The solutions to these tactics are simple once understood.

4.3.9.9.1. Vertical—Down. A defender using the vertical will be able to exchange potential energy for a high turn rate in an attempt to cause the offender problems. The offender needs to keep the pressure on the defender by matching his rate and using the same potential energy. Do not let much vertical difference build (500 to 1,000 feet is optimum) as you follow the defender down. A higher aspect shot, or a quick solution to a lower aspect shot is not normally presented until the fight reaches the floor. At this point the offender converts to the final gun solution and the defender has little vertical available to complicate the gunshot.

4.3.9.9.2. Vertical—Up. A defender attempting to go over the top opens the offender's missile WEZ and provides the offender with a low cost gunshot at the top. Simply assess if you can achieve a gun WEZ as the defender starts up and then stay in plane with the gun cross on, or in lead, until the bandit reaches the top. If a gun WEZ is not immediately available, fly to a spot just prior to the start of the bandit's pull and follow him up. Lead going up, and lag going down, should solve the problem. Wait until a controllable gunshot is available with the bandit at the top. ***CAUTION***: although you will see a gun WEZ on the backside or at the bottom, pulling lead may cause an overshoot in an area where the defender can reverse and become a threat. If the gun WEZ is available in these areas, a missile WEZ may be there also. A defender using excessive use of the vertical allows the offender to arc the defender and sets up a gunshot as the defender is slow on the top and falling down with limited energy to jink.

4.3.10. Defensive Basic Fighter Maneuvers. The correct mindset is critical to successful defensive BFM; concentrate on surviving for as long as possible. The basic game plan is to first, prevent the attacker from employing ordnance and then force the attacker to make mistakes that allow the defender to neutralize the attack or go offensive.

4.3.10.1. Objectives. The primary objectives of defensive BFM are:

- Deny WEZ and ordnance.
- Create maximum geometry problems for attacker.
- Recognize and exploit errors.
- Effective Jinks and infrared missile defense (IRMD).

4.3.10.1.1. Current Environment. Today's air combat environment is very lethal. Practically all-modern fighters have advanced radar and IR-guided missiles, and all but a few carry internal guns. Radar missiles typically have long effective ranges that preclude being able to run away (bug out/blow through) from a visual encounter. Even from a high speed, 180-degree AA pass, the least capable medium-range missile (MRM) usually provides the bandit a shot opportunity at the fleeing fighter. IR-guided missiles get more lethal every year as new types are developed, and older models are upgraded. Second- and third-generation IR missiles not only had small WEZs but could also be reliably defeated by flares, newer short-range missiles (SRM) have large off-boresight slave angles and robust counter-countermeasures (CCM). These advances in SRM technology have made the old check and extend defensive game plan largely obsolete. Today, about the only sanctuary left in the visual arena is in tight; inside the minimum range for threat missiles, and/or outside their slaving limits, while avoiding the bandits nose (the gun WEZ). The defensive plan will focus on rapidly getting to and maintaining this sanctuary, while carefully watching for an exploitable bandit error.

4.3.10.1.2. Priorities. Here are a few “basic, simple truths” of defensive BFM.

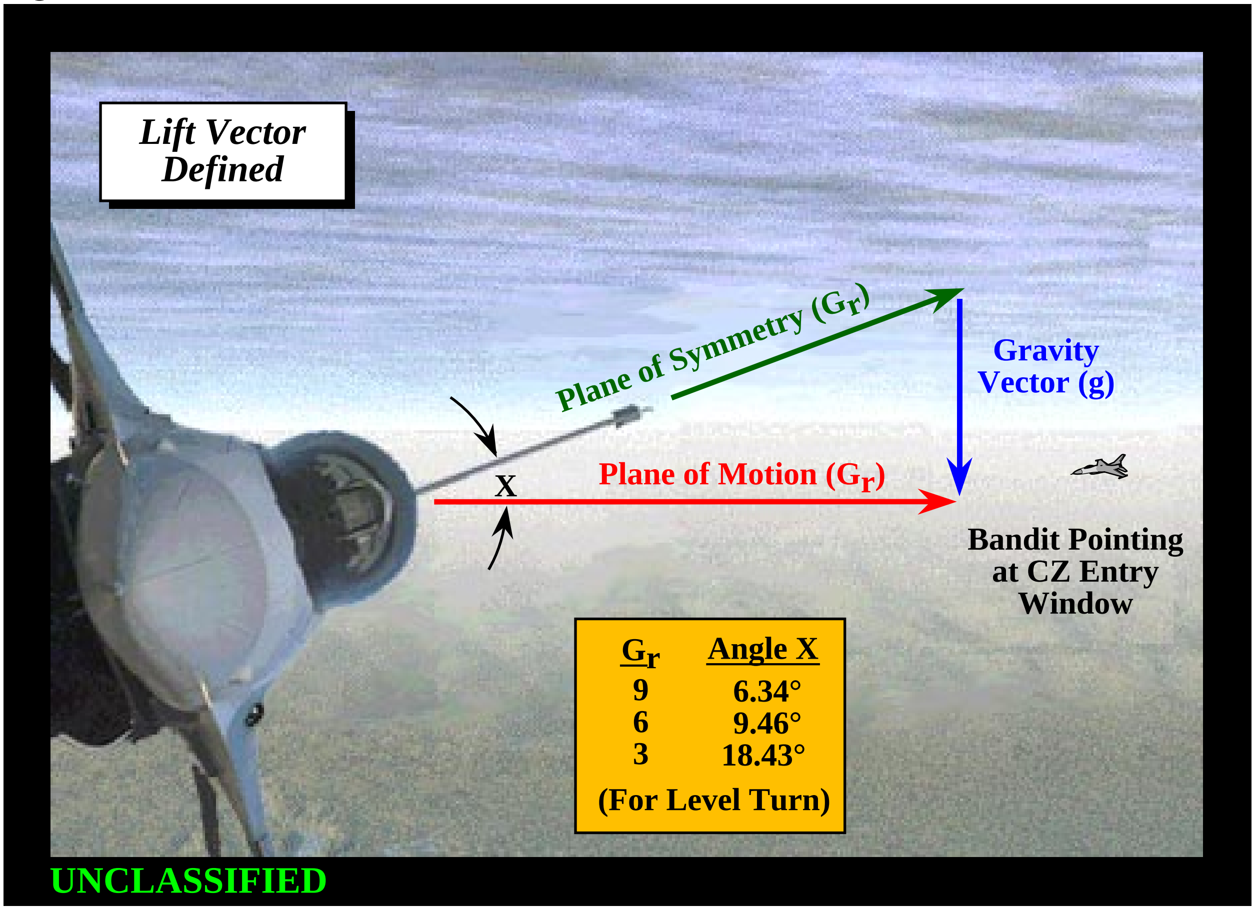
- ***Survive***. As previously stated, survival is the most important priority in defensive BFM.
- ***Create bandit BFM problems*** while recognizing and exploiting any BFM errors (as long as it does not conflict with survival).

4.3.10.1.3. Priorities Guide Actions. Fully understanding this priority hierarchy can help simplify your defensive decision-making. For example: An AB initial break turn would significantly increase the angles turned over time by the defender, and complicate the bandit's follow-on maneuvering. However, that AB break may nullify any IR countermeasures (CM) efforts and allow a quick IR missile kill by the bandit, with no follow-on maneuvering required. Therefore, AB breaks are tactical suicide. Also, guns defense frequently suffers when defenders are reluctant to give up the “turning room” required to effectively get out-of-plane for a medium-aspect guns jink. The jink helps solve the bandit's closure and angles, but not jinking can be fatal—dead men do not reverse. Creating BFM problems overrides P_s management as long as problems are really being created. Continuing to bleed off airspeed in a limiter pull, while a well-flown bandit drives into your deep 6 o'clock for a heater fails the common sense test. Continuing a limiter pull that is effectively moving the bandit forward on your canopy is smart. If using up all your knots will pull the bandit all the way into the HUD, then use up all your knots (and gun him)! It is a simple matter of priorities.

4.3.10.2. Initial Break Considerations. Lv control, visual cues for Tc entry, and head positioning to maintain tally-ho are critical to an effective break turn.

4.3.10.2.1. Lv Control. Lv placement is critical to effective defensive maneuvering. (See **Figure 4.21.,** Lift Vector Defined.) For typical break turns of 7 to 9 Gs, Lv is no more than 10 degrees off the canopy reference line (vertical tail) even for a worst case level break. Initial break turns with the vertical tail pointing at or slightly above the bandit are "close enough." This will result in a slight descent relative to the bandit.

Figure 4.21. Lift Vector Defined.



4.3.10.2.2. Visual Cues. At lower G loads the POM will be displaced significantly further from the plane of symmetry. The main visual cue here becomes bandit position relative to the horizon. If the bandit is not making any big out-of-plane maneuvers, a Lv-on turn should hold the same relative position with reference to the horizon. Lv below the bandit will cause the bandit to move higher relative to the horizon. Lv above the bandit will cause the bandit to move lower relative to the horizon. Of course, these same concepts apply to high G turns as well, though just pulling the bandit straight down the canopy line may be easier to visualize at higher G.

4.3.10.2.3. Head Positioning. Improper head position during high-G defensive turns is a common error. The first instinct is to attempt to support the weight of your head and helmet using your neck muscles alone. This is pretty difficult, and can lead to serious muscle injury at F-16 G-levels. Equally unacceptable is the practice of looking at the bandit under low-G, looking forward and turning hard, then looking back to reacquire the bandit after the speed and Gs bleed down. You cannot exploit a pursuit error you do not see. The best technique is to use the seat headrest to support your helmet during the turn. A right turning break example is: As you begin the roll to Lv-on, rotate your upper torso about 45 degrees right, and lean your upper body slightly to the right. Turn your head to the right another 45 degrees or so and tilt it back just enough that you can see the bandit on the reference line with your eyeballs at their extreme upward and left "slave limits." This position will place the right side of your helmet against the lower left side of the ejection seat headrest. Let the headrest support the weight of your helmet and you will be able to turn very hard in relative comfort, while watching the bandit. By rolling your helmet against the headrest and moving your eyes, you can follow the bandit through a wide range of maneuvers. (See **Figure 4.22.**, Head Positioning.)

4.3.10.2.4. Jettison Considerations. The majority of F-16 combat ordnance loads are CAT III. While most pilots have some established criteria for when they will jettison their external stores, discussion of the actual switch movements involved rarely include references to the stores category switch. Punching only the emergency stores jettison button will not provide the bandit with "a face full of CAT I Viper." It will result in a CAT III Viper with no jettisonable stores remaining unless the stores category switch is also moved to the CAT I position. This is a fairly labor intensive series of switch changes to make while in a break turn. Also, when the Gs slam you back against the seat, it is a long reach for most pilots. You need to spend some time thinking about the impacts of this to your go-to-war switchology and habit patterns.

4.3.10.3. Surviving the Initial Attack. With the foundation of defensive turn mechanics now built, a discussion on the actual techniques of defensive BFM follows, but first a few notes about the missile already in flight.

4.3.10.3.1. Missile Guiding Cues. As shown in **Figure 4.23.**, Visual Cues—Missile Guiding, rapidly moves forward on the canopy and the horizon during the break turn, (probably to about the 3/9 line) then stabilizes in one spot or slowly moves forward as it zeros out its own LOS rates and guides to impact. If you see this, keep the power back (no higher than Mil), and repeat your optimum CM sequence again, while ensuring you are getting space behind you in the missile field of view (FOV). (See **Figure 4.24.**, Adverse Background.) Typical missile TOF are short—this happens fast!

4.3.10.3.2. Missile Decoyed. As shown in **Figure 4.25.**, Visual Cues—Missile Decoyed, will make a clear move aft (relative to the horizon) as it guides to the CM. It may not appear to move aft much on the canopy at first, due to the hard turn "moving" it forward. However, as range decreases it will appear to rapidly move aft. As stated before, these missiles have short TOF, which when that equals the rest of your life, may seem to happen in slow motion! Congratulations, you are still alive, and the fight can continue!

Figure 4.22. Head Positioning.

Head Positioning

Prior to "fight's on"

In the LV-on break

- Other issues
  - Preflight stretching, practice at EOR, lap belt, kit straps

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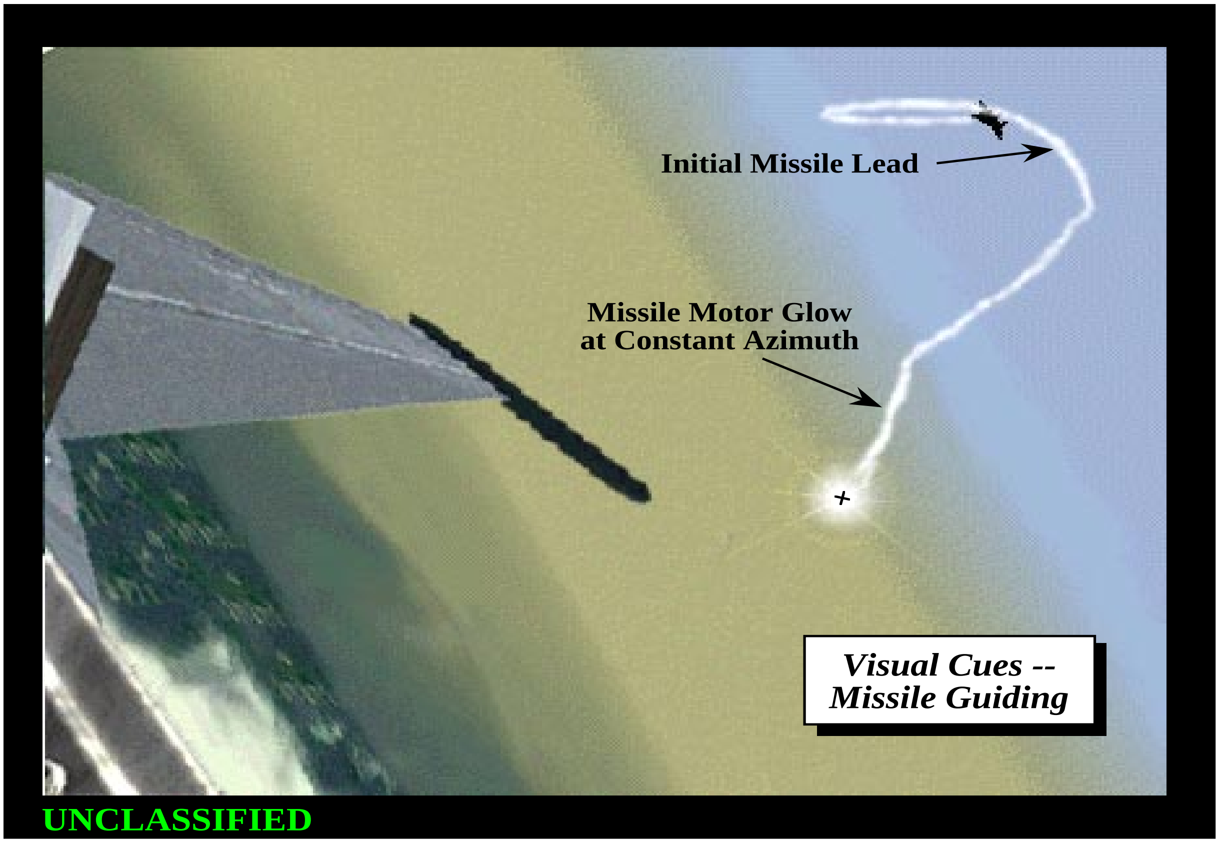
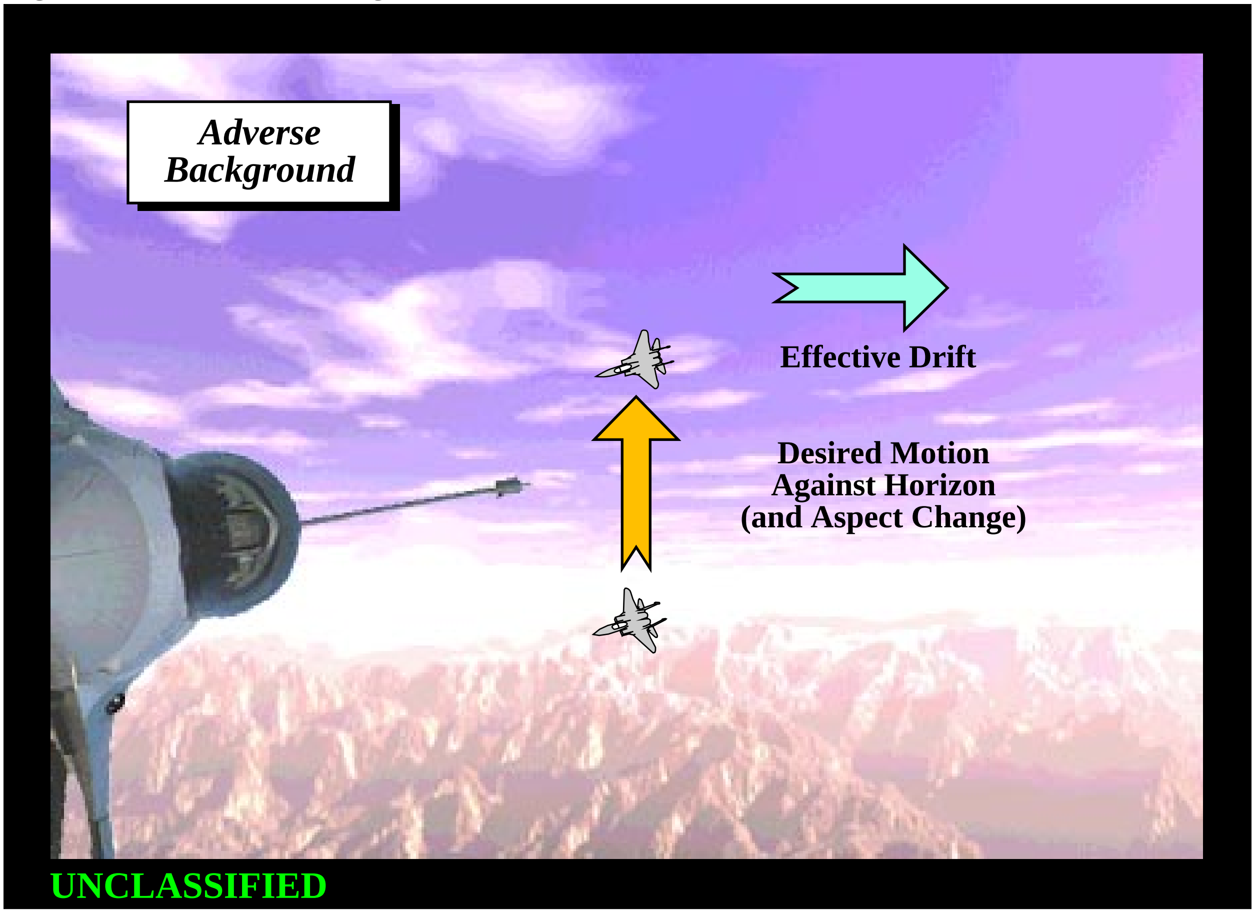
Figure 4.23. Visual Cues—Missile Guiding.



4.3.10.3.3. Follow-on Maneuvering. ***You have survived! What next***? The process of defeating the initial missile attack will probably take 90 degrees of turn. By that point the bandit's chosen pursuit course should become evident. Regardless of the bandit's pursuit course, your Lv-on turn will probably still "work" for at least another 90 degrees. If a large vertical maneuver was required to gain an adverse background, reorient the Lv back to the bandit. Your turn is "working" if you are able to continue to move the bandit forward on your canopy (i.e., toward the HUD). This is part of the second "basic simple truth" of defensive BFM—if your turn is effectively moving the bandit forward or making him bigger, keep turning! You are creating an increasingly difficult BFM problem for the bandit, and the more your AA and HCA approach 180 degrees, the worse the bandit's problem becomes. The major questions to answer as you continue beyond the first 90 degrees of break turn is:

- Are you causing BFM problems in AA, HCA, or range?
- Does the bandit have a WEZ? Accurate AA analysis is the key. (See **Figure 4.26.,** Bandit Planform Views.)

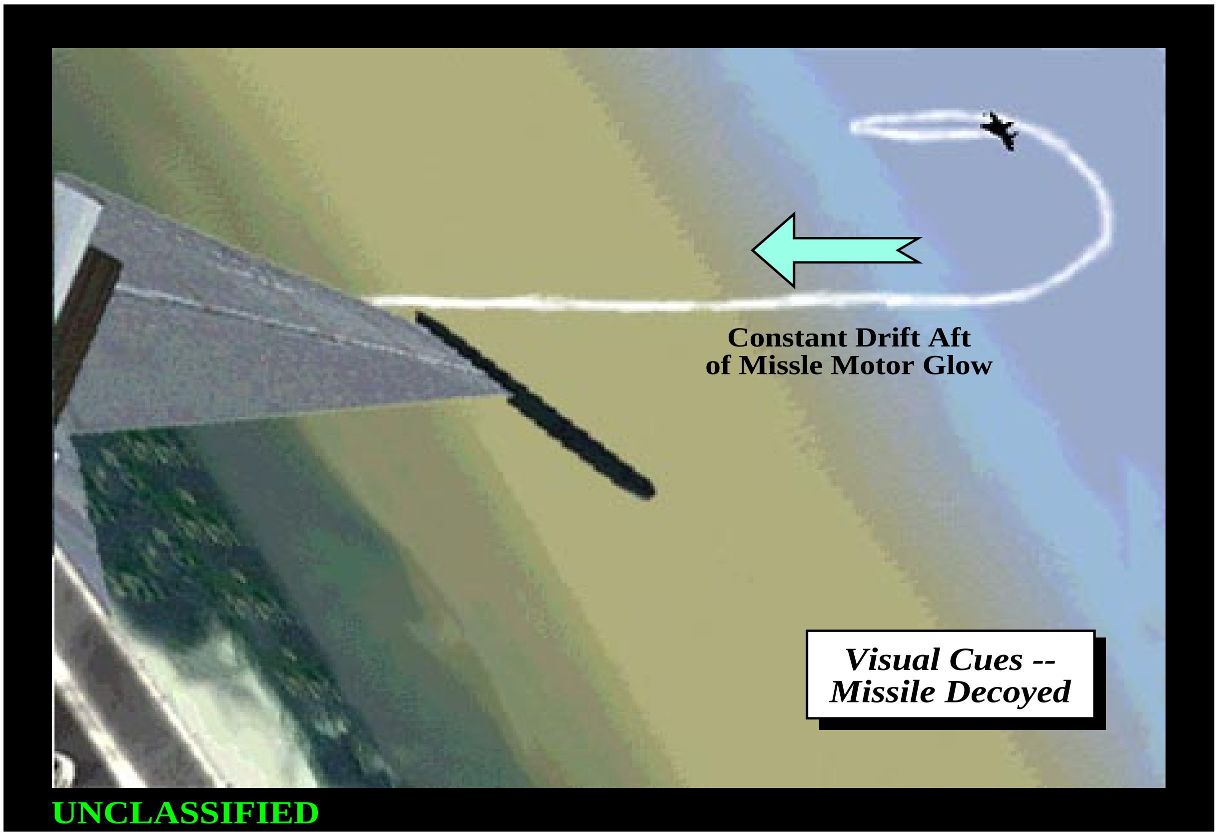
Figure 4.24. Adverse Background.



4.3.10.4. Bandit Pursuit Analysis. While tally-ho during the break turn, you should have a good idea of where the bandit is going based on the pursuit curve: pure, lead, or lag.

4.3.10.4.1. Pure/Lead Pursuit Curves. The visual cue for pure pursuit is obvious, the bandit remains in his initial nose-on pursuit course. (See **Figure 4.27.**, Pure/Lead Pursuit.) The hard turn will rapidly move a pure pursuit bandit forward on the canopy, and for initial bandit ranges of greater than 2 NM you may actually pull the bandit to the HUD prior to the merge. As range decreases, and the bandit enters your Tc, there will be some apparent aft movement. This is because, though the bandit is in pure pursuit, his flight path is actually pointing behind you by an amount equal to his AOA. A bandit who remains in pure pursuit may be either making a basic error (HUD BFM), or pressing a missile attack to minimum range and setting up for a separation. Either of these could include a high-aspect gunshot attempt. An example of some questions to ask are: What is the minimum range for the bandit's missiles at this aspect? Does the bandit even have a gun? Can the bandit fire it in this configuration? Is the bandit's gun canted up, down, or aligned with aircraft boreline? What is its effective range? (***NOTE***: Current threat knowledge is important.) A pure pursuit bandit presents a very straightforward application of the basic turning rules of thumb presented so far: Break Lv-on to slightly low as described. Use IRCM and a reduced throttle setting. Select AB as soon as you are inside R_{min} for the bandit's missile. Keep the high G turn coming (continue to move the bandit toward the HUD) unless the bandit pulls lead for a guns attempt. Jink out-of-plane if uncertain. The best option is to accurately predict the bandits shot and jink appropriately. Early jinks solve the bandits BFM problem and allow a lower aspect gunshot.

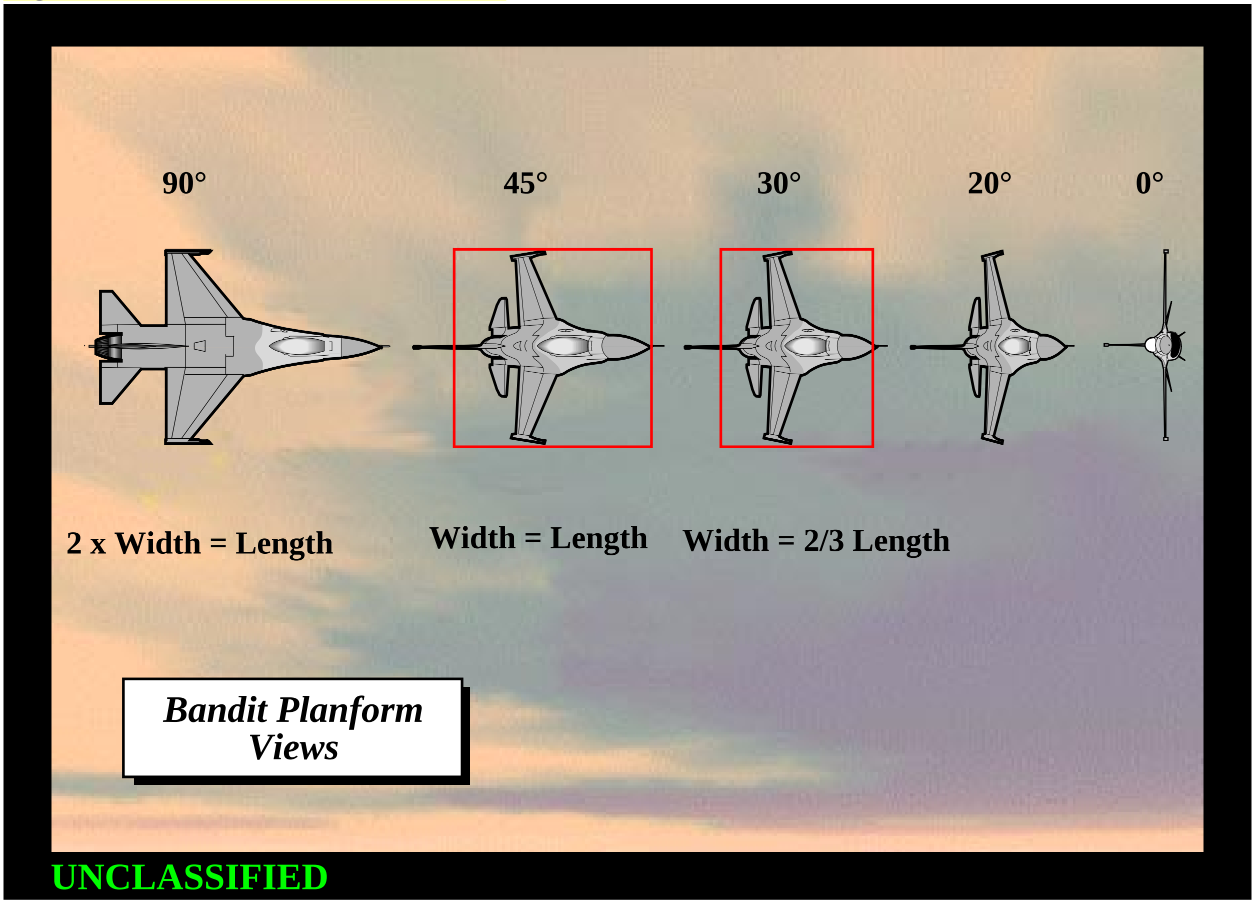
Figure 4.25. Visual Cues—Missile Decoyed.



4.3.10.4.2. High-Aspect Overshoots. Defenders have two options after a bandit overshoot at the initial merge. They can either continue the turn or reverse the turn.

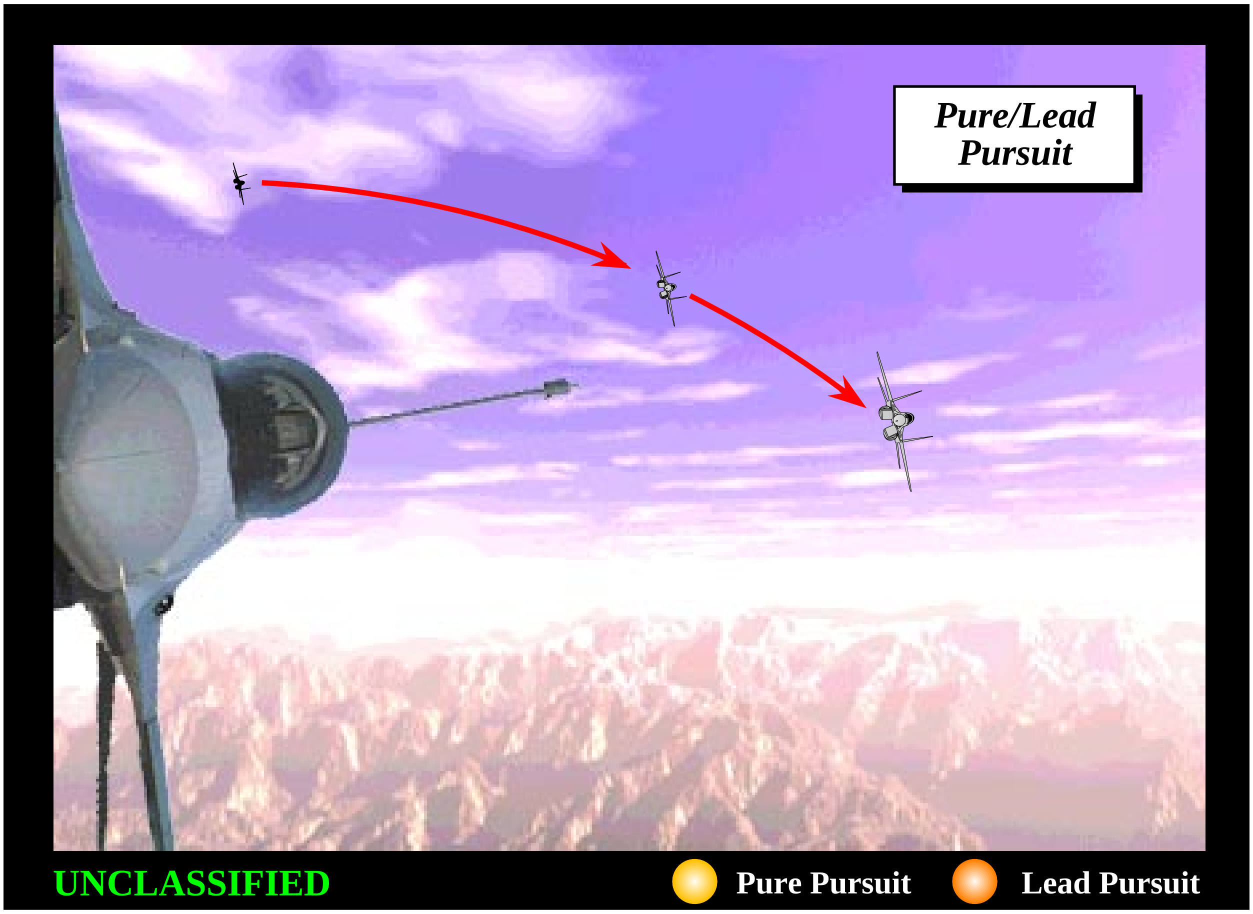
4.3.10.4.2.1. Pure Pursuit Bandit—Turn Direction Maintained. If, after the merge, the turn continues in the same direction, the bandits turn rate advantage, coupled with the associated larger radius, will solve the HCA and AA problems. (See **Figure 4.28.**, Pure Pursuit Bandit: Turn Direction Maintained.) The bandit is able to achieve at least a medium-aspect missile WEZ or even a sustainable control zone (CZ) position. A better option is to choose a flight path that exploits the only real advantage currently enjoyed over the bandit: a smaller turn radius.

Figure 4.26. Bandit Planform Views.



4.3.10.4.2.2. Pure Pursuit Bandit—Turn Direction Reversed. Reversing your turn direction places the bandit in a position where he will quickly move forward of your 3/9 line. Executing the turn reversal involves nothing more than a quick unload, followed by a crisp 180-degree roll to place Lv on to slightly below the bandit, then resume the AB limiter turn. The bandit's larger turn radius will move him forward of your 3/9 line unless the bandit makes an immediate power (airspeed) reduction. If he does this, he may avoid going defensive, but the fight is now rapidly neutralizing, which means you are doing great! If HCA was not too great at the merge, or if the bandit's overshooting flight path was more than a couple thousand feet aft of your position, the turn reversal may not take you permanently out of the bandit's WEZs. It will, however, dramatically reduce the bandit's weapons employment opportunities, and force the bandit to reduce power to preserve 3/9. (See **Figure 4.29.**, Pure Pursuit Bandit: Turn Direction Reversed.)

Figure 4.27. Pure/Lead Pursuit.

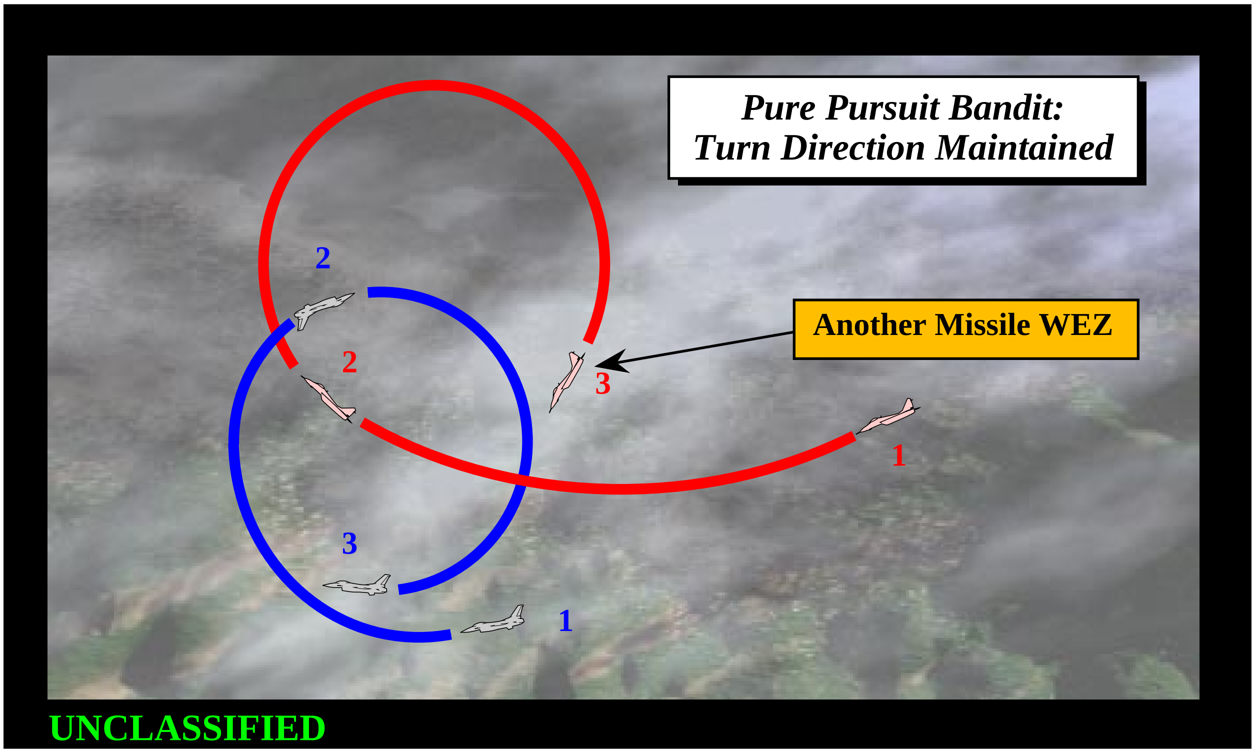


4.3.10.4.2.3. Bandit Initial Guns Attack (Lead Pursuit). The guns attack will be evident when some of the bandit's belly side becomes visible as lead is pulled.

4.3.10.4.2.3.1. Assuming the bandit starts out at your 6 o'clock, HCA at the shot will probably be about 90 degrees if the bandit “pure pursuits” from initial ranges of 6,000 feet and could be up to 180 degrees for start ranges outside of 2 NM.

4.3.10.4.2.3.2. The lead required by the bandit for a 90-degree gunshot is significant, and the belly side should be clearly visible. However, as aspect increases beyond 90 degrees, lead required decreases. If detected early, strive to maintain 90 degrees aspect until the overshoot. At higher aspects the minor differences between pure pursuit and guns attack lead pursuit may be impossible to distinguish, especially under high G loads. When in doubt, execute high-aspect guns defense! In this case a jink out-of-plane should suffice to destroy the bandit's gun solution.

Figure 4.28. Pure Pursuit Bandit: Turn Direction Maintained.

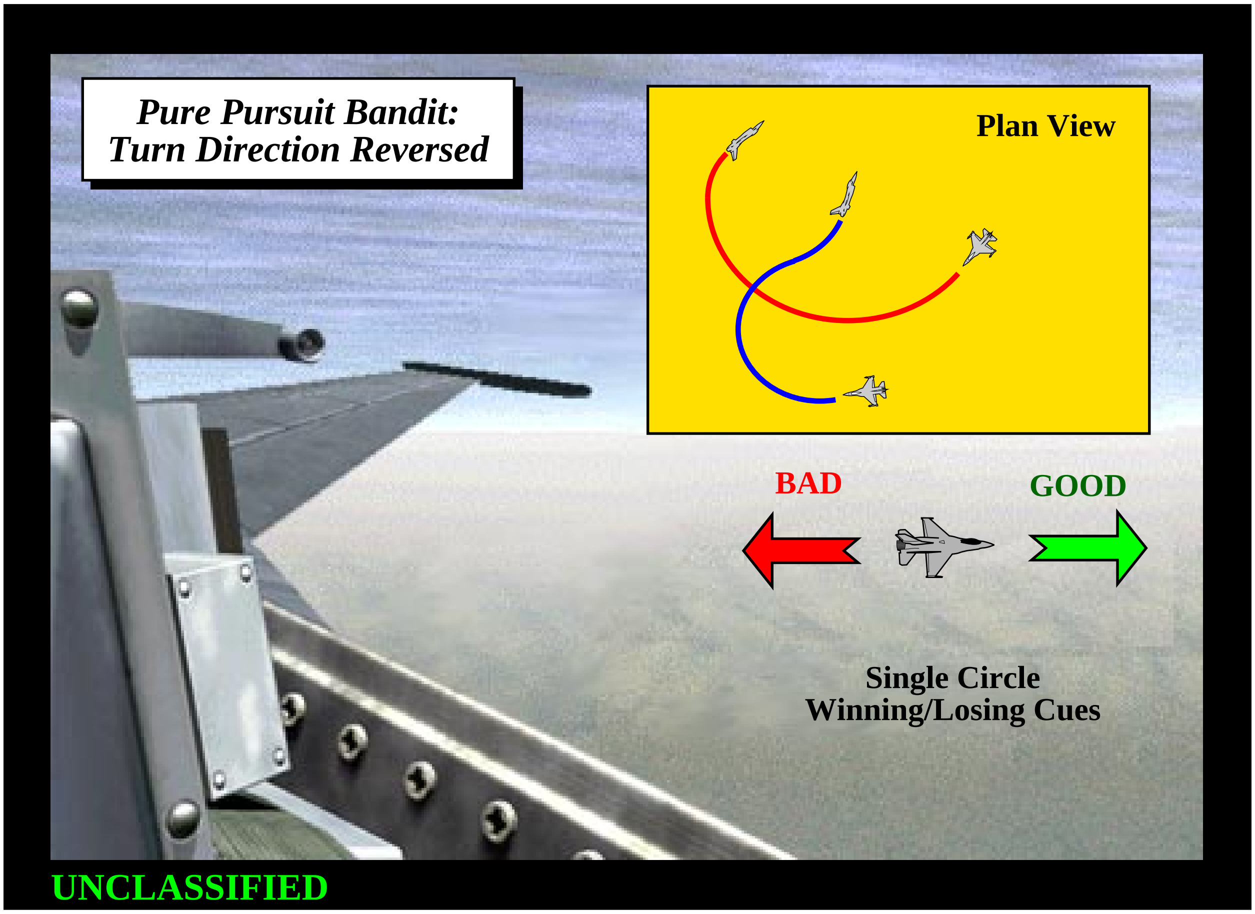


4.3.10.4.2.3.3. It is critical to realize that lead required is a very threat-specific quantity. Some aircraft, such as the F-16, have guns which are aligned with the aircraft boreline. Others, typically dedicated A/A platforms, have guns canted up (reducing airframe lead required), and some A/G fighters have guns canted down (optimized for strafing). Different ammunition types have dramatically different muzzle velocities. What this means is that the visual picture developed for jink timing against an F-16 adversary may not be the same for other threats.

4.3.10.4.3. High-Aspect Guns Defense. Remember the three elements of an effective gunshot. The bandit must solve for lead, range, and POM.

4.3.10.4.3.1. Variables. A quick look at the high-aspect situation reveals that range cannot be denied, the bandit will close into lethal range regardless of anything you do. Likewise, since AA is at least 60 degrees, there is nothing further you can do to deny the bandit from achieving the required lead. What you can deny very effectively in the high-aspect guns defense is POM.

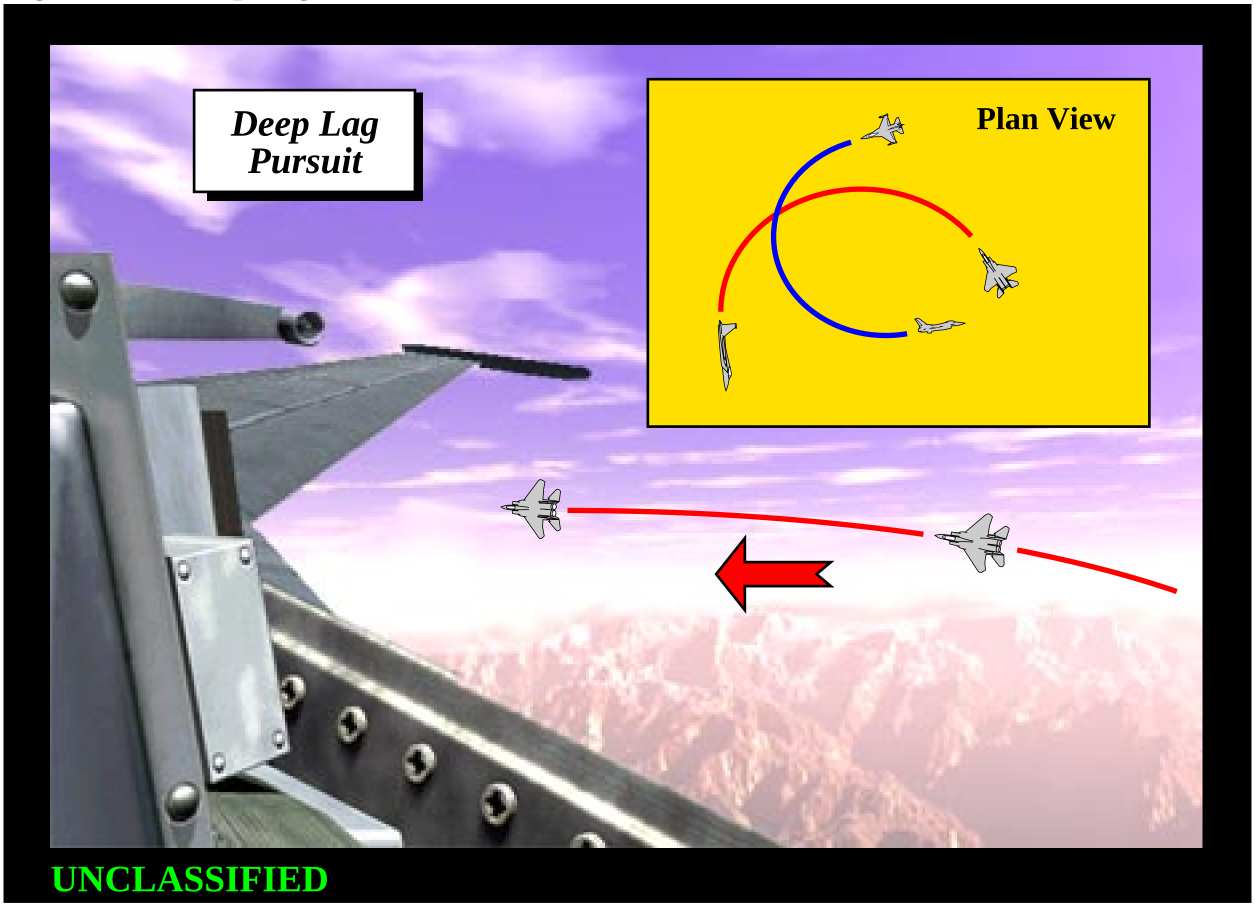
Figure 4.29. Pure Pursuit Bandit: Turn Direction Reversed.



4.3.10.4.3.2. Defensive Maneuver. Roll Lv off the bandit by 45 to 60 degrees and pull until current POM is moved far enough outside the bandit's plane, the bandit will not be able to get his gunsight on you prior to overshooting. Generally, this roll and pull should be down (maximizing total G for a given available radial G) unless already at minimum altitude. Only 1 or 2 seconds of downward pull is required to displace POM adequately. Pull back up, below the bandit, to stop your descent and establish a new parallel POM below the bandit's and build HCA. Timing is critical here! If you begin your jink too early (and even worse, roll back Lv-on too early) the bandit has time to solve POM again prior to minimum range. If you begin your jink too late, the bandit has time to complete guns attack (i.e., kill you!) before POM has effectively changed. A good rule of thumb is to begin the roll as soon as you see a definite pull to lead pursuit by the bandit, or by 3,000 to 4,000 feet slant range if AA is too high for reliable lead pursuit visual cues.

4.3.10.4.4. Deep Lag Pursuit. Late G-onset or flying (way) out the back of the Tc results in deep lag pursuit. (See **Figure 4.30.**, Deep Lag Pursuit.) The bandit makes an initial move generally in the right direction, but instead of beginning a properly timed turn at the CZ entry window, the bandit delays this turn and flies out the back of your circle.

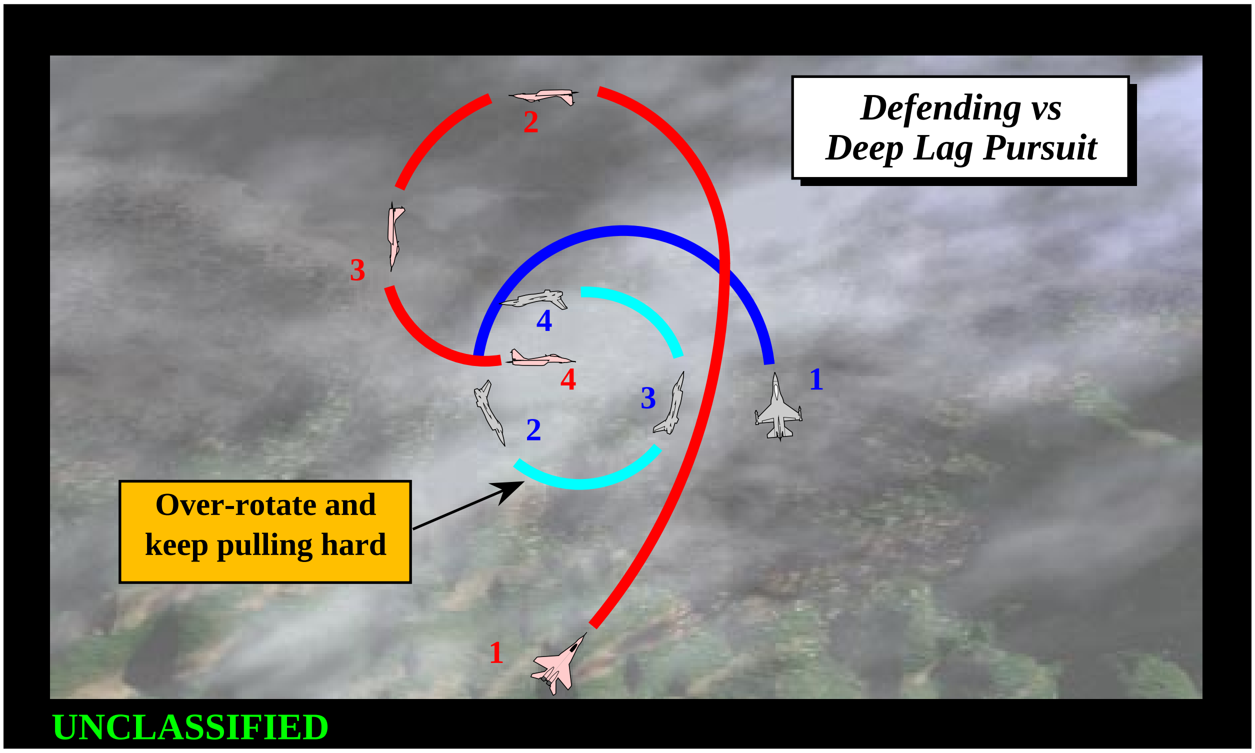
Figure 4.30. Deep Lag Pursuit.



4.3.10.4.4.1. Visual Cues. During your break turn, the bandit will move forward, but as the bandit reaches your Tc you will see either constant or still increasing, HCA. Also, the bandit's late turn will result in range increasing briefly after about 180 degrees of break as the bandit's late turn produces momentarily diverging flight paths.

4.3.10.4.4.2. Defending Versus Deep Lag Pursuit. Reversal into the previously discussed "single-circle" geometry is probably not a good option unless the slant range to the bandit at the pass is close (i.e., no greater than 3,000 feet). This bandit flight path is approximately pure pursuit and is handled as discussed in **paragraph 4.3.10.4.2.1**, Pure Pursuit Bandit—Turn Direction Maintained, and **paragraph 4.3.10.4.2.2**, Pure Pursuit Bandit—Turn Direction Reversed. Reversing with greater slant range will present the bandit with an available (albeit high aspect) gun WEZ, and possibly a WEZ for some advanced IR missiles. Continue the turn and deny any future WEZ by over-rotating low to increase the turn rate. The effect of the momentarily divergent flight paths will be that you can effectively move the bandit forward on the canopy (basic truth #2 applies!). Keeping the turn tight will reduce range available to the bandit such that nose-on/lead for a gunshot at the next pass cannot be achieved. (See **Figure 4.31.**, Defending Versus Deep Lag Pursuit.)

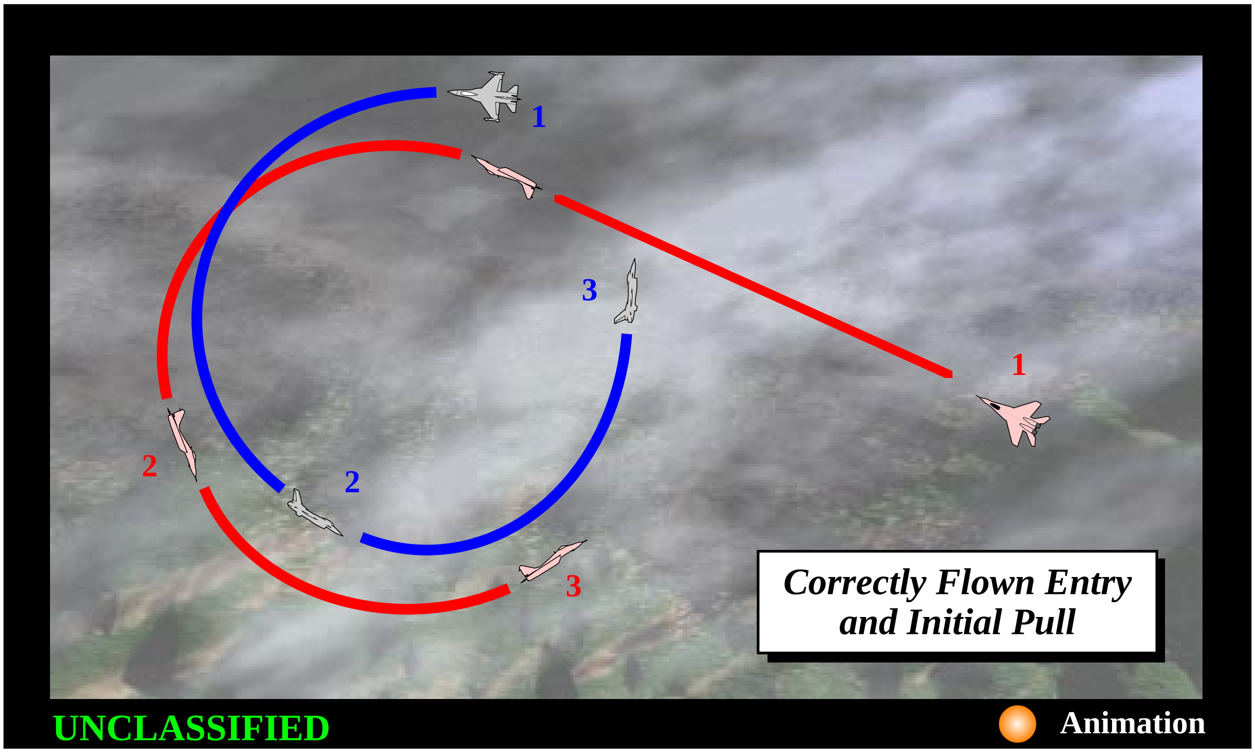
Figure 4.31. Defending Versus Deep Lag Pursuit.



4.3.10.4.5. Correctly Flown Entry (Smart Bandit). "Correct" offensive BFM represents the worst case for the defender as shown in **Figure 4.32.**, Correctly Flown Entry and Initial Pull. Initial visual cues, as the bandit extends toward the "window," will be that your turn is working. Move the bandit forward to greater than 45 degrees ATA. Then, when the bandit begins turning (solving HCA and AA problems), the cues begin looking worse. Forward canopy movement stops, and despite your best turn, the bandit begins tracking back aft on the canopy. Also, HCA is clearly decreasing and range is far enough aft that the bandit's available rate and radius will be enough to achieve guns parameters. The offender is approximately 4,000 to 6,000 feet away, between 45 to 90 degrees ATA. The bandit has arrived in a currently unexploitable (by you!) position.

4.3.10.4.5.1. Selecting a Fight. The defender can either elect to continue maximum rate and full AB to cause the bandit the maximum problems in the short term, or transition to a constant turn defense (CTD). Instead of an immediate gamble, this is the preferred tactic. The CTD preserves the defender's survival by denying a WEZ to the offender, keeps presenting a difficult BFM problem to solve and allows time for the defender to either make an exploitable error or for help to arrive.

Figure 4.32. Correctly Flown Entry and Initial Pull.



4.3.10.4.5.2. CTD Execution. The execution of the CTD is very basic: keep the attacker from killing you now while preserving energy to keep him from killing you later. The only option to stay alive in the modern visual fight is to stay out of a WEZ. The only options to accomplish this are to either stay far off the bandit's nose and/or inside the WEZ. The “in too tight” cues and actions have been previously discussed. The CTD attempts to keep the bandit’s “nose” off the defender as long as possible. The defender must transition from the break turn to the CTD while outside the bandit's WEZ. A quick look at airspeed will inform the defender of immediate Lv placement. As airspeed decreases below 300 knots, the defender must lower the Lv to keep the airspeed around 275 KCAS (this airspeed produces a good tradeoff between maximum sustained rate and minimum radius). A 325-knot turn at 0 P_s is roughly 700 feet bigger in radius (and 1,400 feet larger in diameter) than a 0 P_s turn at 275 knots. The extra energy bleed from 325 to 275 also presents a tougher initial BFM problem for the attacker. The drawback is that there are fewer knots to “clamp” with as the attacker attempts to put the nose in lead. If improperly timed, this extra airspeed may never be used due to the power reduction as the offender gets the nose within 45 degrees and IRCM (survival) takes precedence. The larger turn diameter also presents a much larger WEZ for the attacker, once again, not optimum. As airspeed decays below 275 knots, to keep the attacker out of a WEZ the defender must lower the Lv to keep the kinetic energy level up (obviously at the expense of potential energy and offering “free” turning room to the offender). Remember: the goal is to hold the bandit off with at least 45 degrees aspect. Keep this hard turn coming as long as it is working. A typical error in the transition from the “break” to the CTD, is to let up on the G instead of just rolling the Lv low as the G steadies out around 4 Gs. The few seconds of unload to 2 to 3 Gs takes the defender's rate down to approximately 5 to 9 degrees per second with a turn radius of 4,000 to 6,000 feet, making the turning room problem for the attacker that much easier to handle. As shown in **Figure 4.33.**, CTD Basics, CTD defender actions are outlined.

Figure 4.33. CTD Basics.

CTD Basics

1. **Light AB ASAP when out of WEZ (approximately 45° ATA).**
2. **Flare until out of WEZ, expend them as the offender approaches 45° ATA.**
3. **Pull to stay out of a WEZ (>45°).**
4. **Orient Lift Vector to keep an optimum airspeed (250 - 300 KCAS).**

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4.3.10.4.5.3. Transitioning to Guns Defense. The time to come out of this CTD “crouch” is when the CTD is no longer working.

4.3.10.4.5.3.1. The bandit flys toward your 6 o'clock, losing Tally-ho becomes a factor.

4.3.10.4.5.3.2. Attacker rotates toward the defender and aspect falls below 135 degrees. The bandit has a WEZ! Recognize this and take action prior to a bandit shot opportunity; time to clamp.

4.3.10.4.5.3.2.1. A late clamp may allow the attacker to get within a WEZ, forcing full-up IRCM.

4.3.10.4.5.3.2.2. A correctly timed clamp may allow the defender to stay in full AB, and present a problem the attacker may not like, or be able to handle.

4.3.10.4.5.4. The Clamp. The clamp mechanic is fairly simple, put the Lv on to slightly below the defender and pull as hard as possible. The purpose is to take turning room away while creating higher aspect. The attacker has several follow-on options:

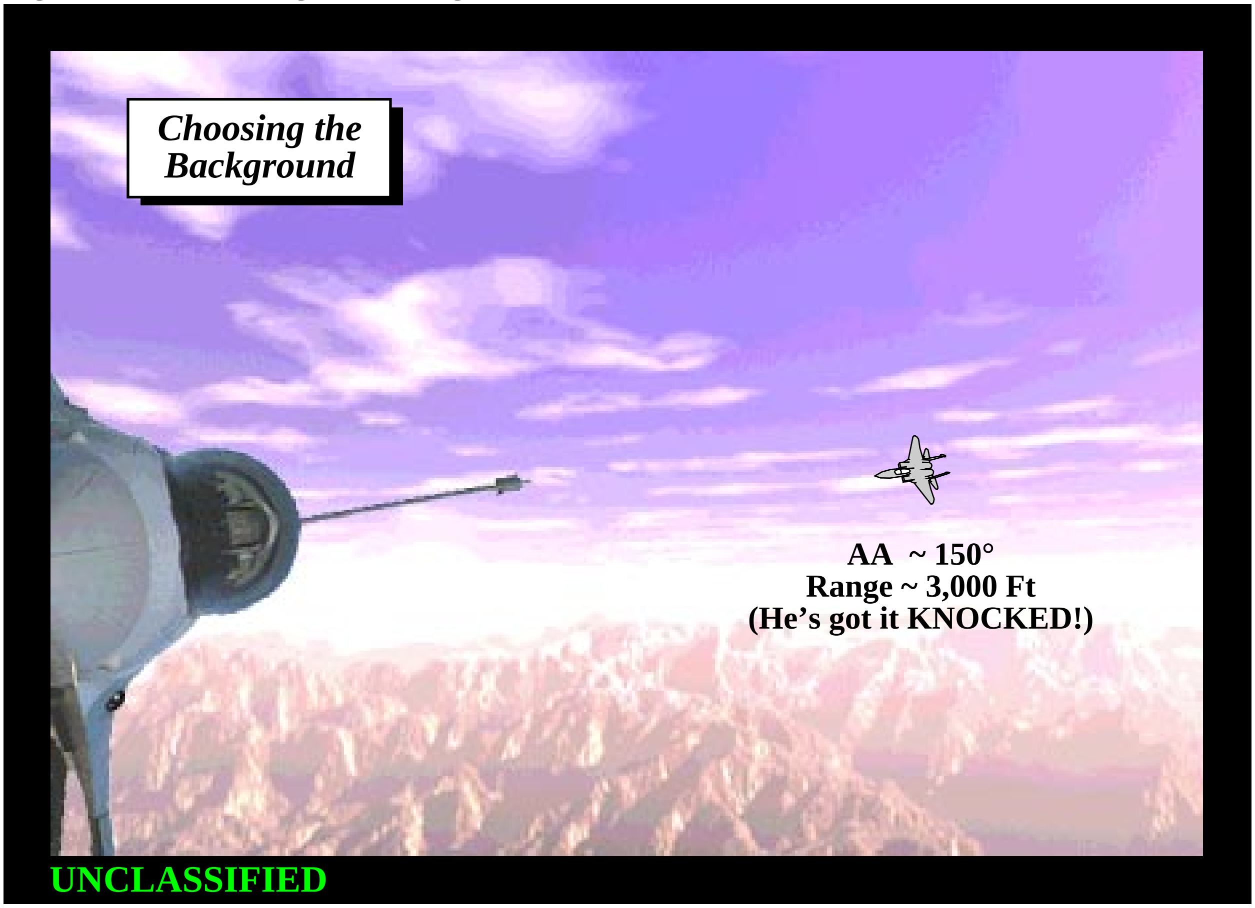
4.3.10.4.5.4.1. The problem the attacker now faces could be too much so the attacker repositions. Hopefully an exploitable error that you can now take advantage of has been forced.

4.3.10.4.5.4.2. The attacker could prosecute an attack, from which you transition into a missile and guns defense.

4.3.10.4.6. Choosing the Battleground. Prediction is the key; this is basically a risk management concept. If your visual assessment of the bandit's parameters and maneuver capabilities indicate that the bandit will eventually achieve a controllable guns WEZ, you have a decision to make. (See **Figure 4.34.,** Choosing the Battleground.) Normally, it is good guidance to deny a WEZ to the bandit as long as possible. However, the process of temporarily denying the WEZ may significantly degrade your future "defeat ordnance" capability. For example, if you predict you can only deny the guns WEZ for another 180 degrees (at which point you will be on the deck with no airspeed remaining) consider reversing now. This low LOS reversal will allow the bandit an opportunity for a low-aspect missile shot. Use flares and reduce power! The object is to cause the bandit range problems (AA and lead already solvable) while denying a high probability of kill (P_k) gunshot. It will be much easier to defeat a gunshot when you have a couple thousand feet of altitude to work with. By accepting a "worse" situation now, you increase your overall odds of survival. Considerations include the proximity of supporting fighters (if your wingman can kill the bandit in 10 seconds, do not reverse) and bandit WEZ capabilities. Do not reverse unless you are sure the bandit is eventually going to get you. Visual cues may indicate the bandit is stuck in lag.

4.3.10.4.7. Countering a Low Yo-Yo. Visual cues for detecting a Low Yo-Yo are the bandit's nose and flight path dropping in relation to the horizon as the bandit's Lv reorients into lead. Countering a Low Yo-Yo is fairly simple as shown in **Figure 4.35.,** Countering a Low Yo-Yo. Overbank by an equal amount to keep the bandit in the same position relative to the horizon. This should keep the bandit's nose stuck in lag. It will also accelerate your closure with the ground/floor. As you approach the deck, a well flown "floor transition" may provide an offensive opportunity. It is important to take the offensive opportunity. Sticking the bandit in lag only ensures temporary survival. The fight will be won or lost based on several factors:

Figure 4.34. Choosing the Battleground.

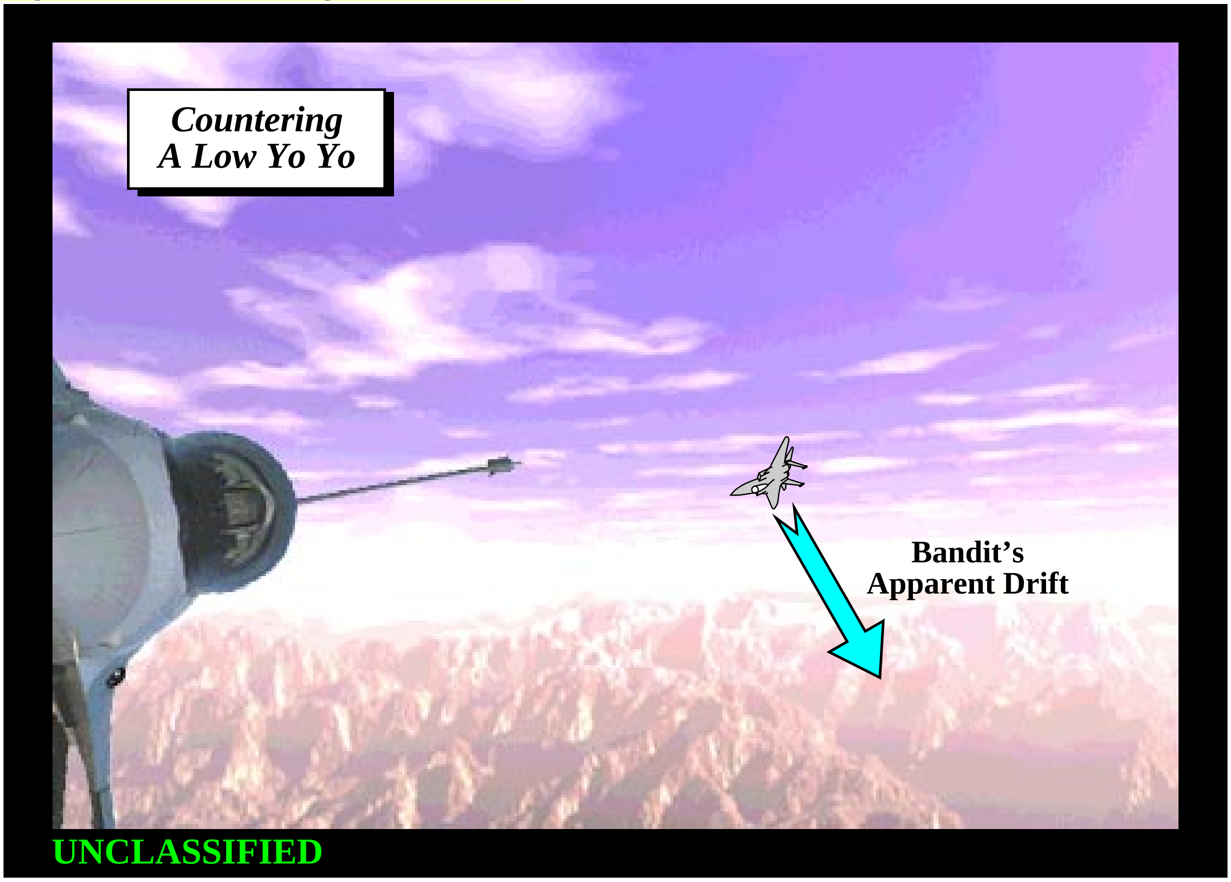


4.3.10.4.7.1. First, the fight is not being fought in a tactical vacuum. You both probably have supporting fighters somewhere in the vicinity. The winner will be determined by whose supporting wingman arrives and fires first.

4.3.10.4.7.2. Second, disengagement is probably suicide, so if no support is available, you are "locked" together in combat until one or the other of you achieves a kill or runs out of fuel. Therefore, since the reversal game plan is inherently risky, proximity of supporting fighters, as well as fuel and ordnance remaining must be taken into consideration when deciding whether to attempt to improve the present situation.

4.3.10.5. Three Categories of Gunshots. This breakdown of gunshots is oversimplified, since they occur over a wide aspect and V_c regime. Analyze the three components of gunshots—lead, range, and POM—the optimum defensive strategy versus various gunshots will generally break down into one of two categories, either an attempt to deny lead, or an attempt to deny POM. For defensive purposes, separate gunshots into three categories corresponding to their optimum defensive strategies as shown in **Figure 4.36.**, Three Categories of Gunshots.

Figure 4.35. Countering a Low Yo-Yo.



4.3.10.5.1. Gunshot Types. High-aspect gunshots include those attacks occurring at aspects of equal to or greater than 70 degrees, the medium gunshot from 30 to 70 degrees, and the low aspect shots are those at less than 30 degrees. These numbers are, of course, approximations that will change somewhat with other factors (V_c, altitude available, etc.). The high-aspect gunshot defense has already been covered in the lead pursuit attacker section. Now transition to the "I'll survive, and you try to stay behind me" game plan.

4.3.10.5.2. Low-/Medium-Aspect Gunshots. The attacker has not made any exploitable errors yet, but the defender will now give the attacker another series of "hurdles" to jump over. The defender mindset must be to drive the fight whenever possible and take advantage in the close-in knife fight. The attacker, through pure skill, cunning, or luck, has arrived in a gun and missile WEZ. The defender can attempt to turn those advantages that allowed the attacker to reach this position into disadvantages. Typically, when the defender is in gun WEZ, a missile WEZ is not far away. Keeping the power in idle, with speedbrakes extended will cause the most airspeed closure problems for the attacker. Unless the defender is able to deny the attacker from pulling the required lead (trapped in lag), the power should be in idle to present the toughest problem to solve (closure/range). Upon reaching the floor, and either below 175 KCAS, or while attempting to keep the attackers nose off, select AB and close speedbrakes.

Figure 4.36. Three Categories of Gunshots.

THREE CATEGORIES OF GUNSHOTS

- High aspect / High LOS / High V_c
  - Bandit has little time to solve problems you create
  - Usually only one shot available prior to major reposition
  - Bandit's heater WEZ is degraded by LOS rate and V_c
- Medium aspect / Medium LOS / Medium V_c
  - Initially an out-of-plane (OOP) jink
  - May need to follow up with a rolling duckunder as the attack is pressed
- Low aspect, (maybe) low V_c , "saddled up"
  - Bandit has lots of time to solve problems
  - Multiple shot opportunities available with small repositions
  - Heater WEZ is optimized by low LOS and low V_c

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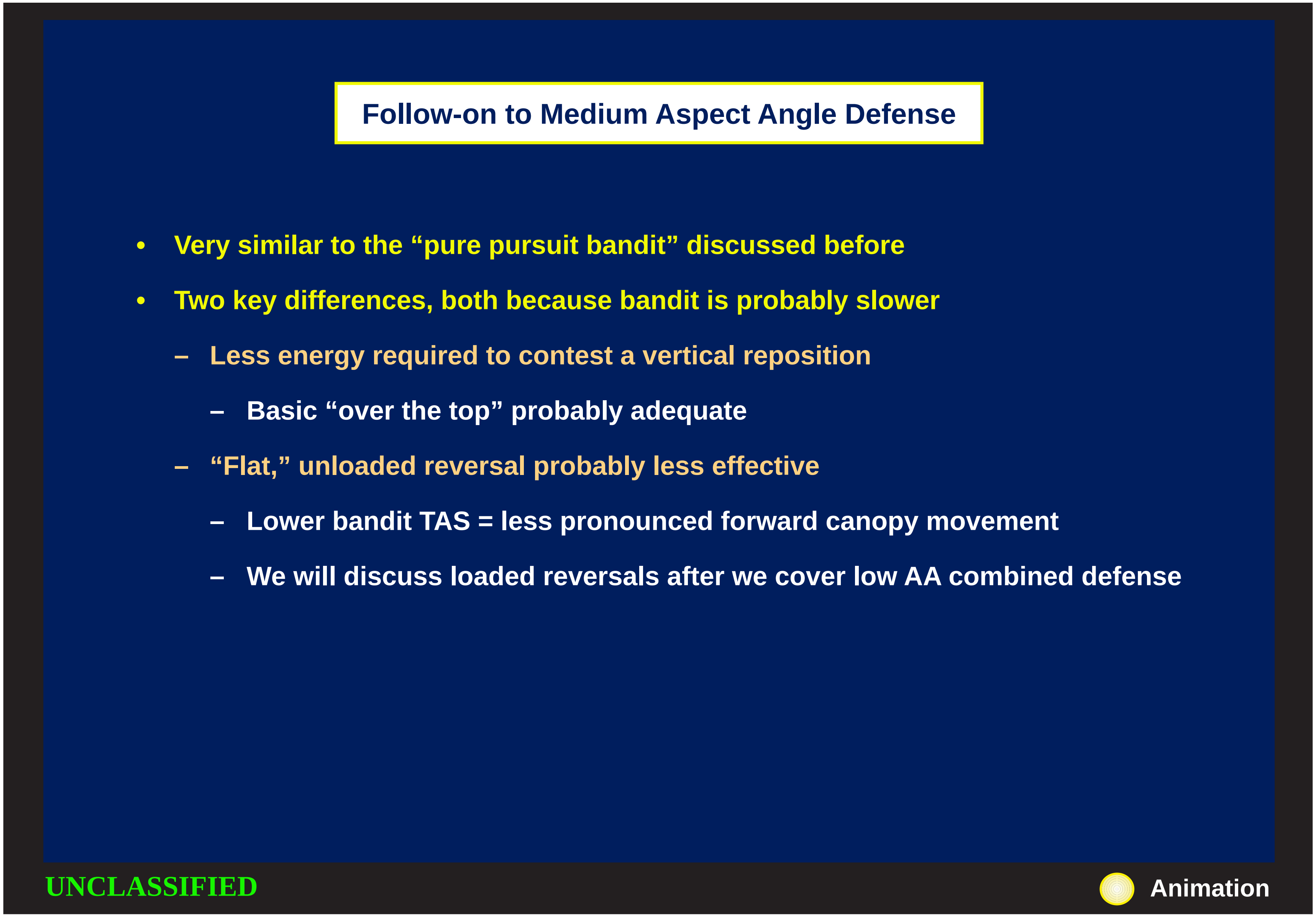
4.3.10.5.3. Medium-Aspect Combined Defense. The two most common errors pilots commit with medium aspect guns defense are: failure to recognize the bandit's WEZ transition, and effectively timing jinks. There will probably be a bandit overshoot following this attack. It is likely a planned overshoot or an attempt to force the defender to react, not necessarily an accidental offensive error. Many defenders get enamored with trying to pull Lv-on to exacerbate the overshoot. Remember: the lethal gunshot is coming first, and jink timing is frequently late. The high V_c of this shot effectively increases the maximum range available to the bandit. Also, since only one opportunity will occur (overshoot), most proponents of this type of shot start shooting early and continue to minimum range. A good "no later than" timing cue is when the bandit's nose passes through pure pursuit. A significant amount of the aircraft "belly" is visible at the open fire point. Establish the maneuver before the bullets are on the way. The execution is either an out-of-plane jink (the higher the aspect/V_c/LOS) or right into a POM spoiling jink (a rolling duckunder if altitude allows) if closer to low aspect.

4.3.10.5.4. Follow-on to Medium AA Defense. Follow-on moves to the medium-aspect shot are much the same as those discussed in **paragraph 4.3.10.4.2.1**, Pure Pursuit Bandit—Turn Direction Maintained and **paragraph 4.3.10.4.2.2**, Pure Pursuit Bandit—Turn Direction Reversed. The one significant difference is that since the bandit came from the CZ into a medium-aspect shot, the bandit is probably going slower than if the bandit charged right in there from your initial break turn. As shown in **Figure 4.37.,** Follow-On to Medium Aspect Angle Defense, this impacts your follow-ons in two ways

4.3.10.5.4.1. First, it reduces the amount of energy needed to contest a vertical reposition by the bandit. If the bandit begins a vertical pull while still inside your turn, over-the-top airspeed should be enough to pull your nose up after the bandit. If you are below over-the-top airspeed extend briefly to get it. If you start up with less energy, the bandit will almost certainly achieve enough 3/9 and vertical separation to remain offensive during the ensuing stack.

4.3.10.5.4.2. Second, it makes an unloaded reversal into single-circle geometry less effective. The forward canopy movement cues will be less dramatic (possibly nonexistent) than those for a higher speed bandit. If you do not see adequate LOS cues as the bandit crosses your flight path, it may be necessary to execute a loaded roll towards the bandit's high 6 o'clock position to exaggerate forward movement. If the bandit stays level, you will quickly be able to reorient Lv into lead for an offensive position. If the bandit reacts with a late pull into the vertical, after you have already begun a nose high reversal, you will probably achieve a position low in the stack with some 3/9 advantage (neutral).

Figure 4.37. Follow-On to Medium Aspect Angle Defense.



4.3.10.5.5. Low-Aspect Combined Defense. At 0 AA, any attempt to reorient POM by the defender can be immediately solved by the bandit simply rolling the Lv into the new POM. As AA increases out to 40 to 50 degrees, this gets slightly more challenging, but still solvable real-time by the bandit. You cannot do much about range other than light the AB and unload, and since this is a combined guns/IR missile defense, that is not an option. Lead angle becomes the most exploitable component of the low-aspect attack. Remembering that "dead men do not reverse," our defense must be optimized for defeating ordnance. Fortunately, the strategy presented here also provides a significant closure problem, and if the bandit tries to solve closure, a HCA/AA problem as well.

- The preferred jink is a rolling duckunder if altitude allows (1,000 to 1,500 feet needed). Continue the rolling duckunders until there is no altitude left to accomplish them, or you have the attacker in trouble (the defender is now driving the fight).
- The purpose of the rolling duckunder is to defeat a gunshot by continuously changing the POM required and create closure problems for the attacker. Once the attacker is in trouble (in range or HCA), unloaded rolls to give lead out-of-plane, will further complicate the attack and exploit the attacker's problems.
- These maneuvers should manifest into a neutral or offensive position. These endings meet defensive BFM objectives.

4.3.10.5.5.1. Rolling Duckunder. This violent out-of-plane maneuver generates maximum HCA and closure problems for the bandit. It is executed by rolling underneath in the direction the defender is currently turning in. As the attacker pulls the appropriate amount of lead and is establishing the proper POM, simply roll the aircraft while maximizing stick pressure. As the aircraft is upside down, relax the pull, keeping the roll input until the aircraft is 90 degrees of bank. Decide whether to come out of the jink and pull in the new direction or continue the roll coming all the way around to the original direction. If the jink is continued to the original direction, simply add full backstick pressure from the 90 degrees point all the way over the top to the original direction.

4.3.10.5.5.2. Jink Exit Selection. Determining departure of the jink depends on where the bandit is going. Since during the execution of this violent out-of-plane maneuver, the defender loses tally, predicting the bandit's intention is the key to selecting direction. Initially this is very difficult to do, but with practice, is easily done.

4.3.10.5.5.2.1. A very aggressive move is to come out in the direction that will put the attacker in lead, out-of-plane. This aggressive option attempts to get the defender in the driver's seat as quickly as possible. It also forces the attacker to bid to lag (start the nose counter to force more V_c problems) or put the nose in lead, once again creating higher V_c. The unload required to put the nose in the new plane will give the attacker higher airspeed and a longer "string" over the ground; this may result in an overshoot.

4.3.10.5.5.2.2. The other option is to come out in the direction that will put the attacker in lag. This option forces the attacker to pull lead to reestablish a gun solution, but does not create as much closure for the attacker.

4.3.10.5.5.3. "Nose-Counter" Jink. This maneuver complicates the bandit problem by giving ***lag*** when desiring ***lead***. It is a rapid, unloaded 180-degree turn reversal. Maneuver timing cues are different from medium-aspect defense since the bandit requires much less lead. The defender needs to initiate the unload maneuver just prior to the bandit's nose coming into pure pursuit. As this cue is materializing, push forward on the stick, breaking AOA, and roll the aircraft with full aileron to the new direction. Pull in the new direction, out-of-plane, to spoil the shot. The roll should be happening just as the bandit reaches pure, and the pull should come on just before the originally predicted lead point is achieved. The idea is to move as far as possible from the piece of sky the bandit thought you were heading for, without giving enough reaction time to correct for a new lead point. If using this to force closure problems, simply match the attackers nose direction. Continue to give the attacker lead, out-of-plane, using the same fight technique. During these maneuvers the unload is the most vulnerable point to missile attack. If the bandit has not shot an IR missile at you during the initial gun attack, it is probably because your LOS rate was too high for missile guidance. When you go into your unloaded reversal, you spend about 2 to 3 seconds with no appreciable LOS rate at all. Modern IR missiles can be fired from very close range, especially with zero LOS during a gun jink. TOF is short, and it will happen during the time you briefly lose sight in the roll. If your adversary is IR missile-capable, you ***must*** assume a missile is coming when you jink: have the power back and expend flares.

4.3.10.5.6. Follow-On to Low A/A Defense. Follow-on maneuvering will work best with about a 10 to 15 degrees nose-low attitude. Immediately reacquire the bandit and assess his intentions. Your power should be back at idle, with speedbrakes optional. Some pilots like to leave the boards in to avoid alerting the bandit of upcoming closure problems. The sight of the boards is often the first reminder to the bandit to analyze closure. Maintain 160 to 180 knots. This regime gives the optimum tradeoff between retaining roll/turn rate authority and creating closure problems. As the bandit comes back nose on, immediately repeat the maneuver (with flares) in the opposite direction. At this point the bandit may be somewhat "on to" your plan, avoid making your second turn reversal exactly 180 degrees (use 150 to 210 degrees). You do not want the bandit to be able to simply roll out and let you fly through the bullet stream. The bandit's HUD BFM is producing a lot of closure. By the third or fourth jink the bandit will have to make a large reposition to preserve 3/9. If the bandit recognizes closure problems early on in the attack, and elects to lag off for closure control, you can immediately postpone "Priority One" and concentrate purely on creating BFM problems. The strategy here is very basic—when he wanted lead; you maneuvered to turn it into lag. Now, when he wants lag, you turn it into lead. As soon as you see the bandit reversing to put his nose back into lag, immediately roll and pull into him to make it lead. Most of the time, having decided the bandit really wanted lag, the bandit will reverse again back to the new lag direction—turn this into lead also. Usually only a couple of these will provide a neutralization opportunity.

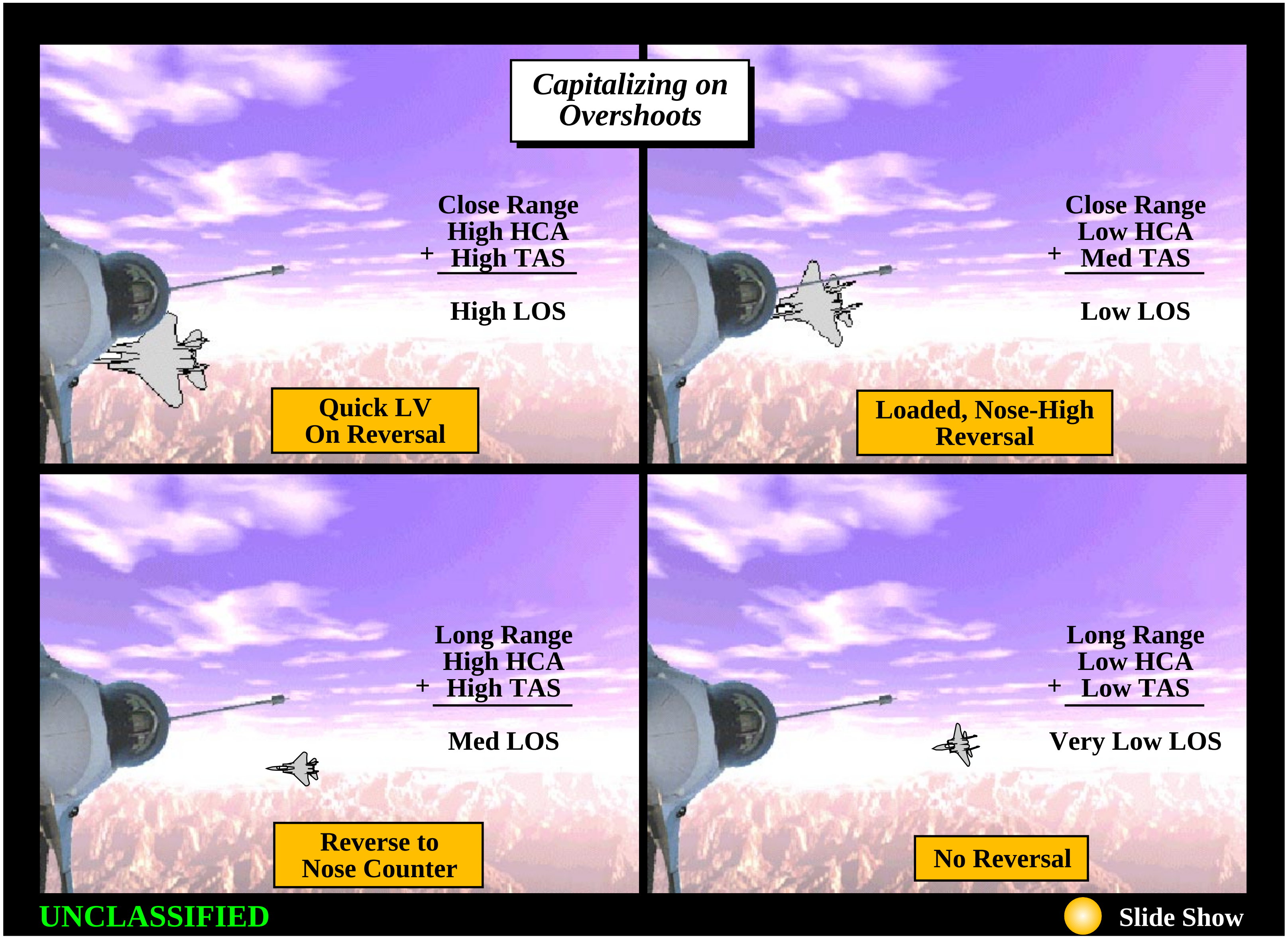
4.3.10.5.7. Capitalizing on Overshoots. LOS rate is the main factor effecting your reaction to overshoots: The range of the 6 o'clock pass, HCA, and bandit TAS produces apparent LOS rate. Highest LOS rate is produced by close range, high TAS, and high HCA. Generally, the higher the LOS rate of the overshoot, the more of a rapid roll to Lv-on your reversal can be. For low LOS rate overshoots, you may need to try to slow your forward motion to increase the apparent LOS toward 3/9. (See **Figure 4.38.,** Capitalizing on Overshoots.)

4.3.10.5.7.1. High LOS Overshoot. The basics of reversing against a high LOS flight path overshoot have been discussed in **paragraph 4.3.10.4.2.2,** Pure Pursuit Bandit—Turn Direction Reversed. It is basically an unloaded roll to Lv-on, reorienting the fight into single-circle geometry, with victory going to the fighter with the smallest turn radius. The contribution of rate is minimal once single-circle geometry is established.

4.3.10.5.7.2. Lower LOS Overshoots. For a successful reversal the defender must exaggerate the LOS by slowing forward motion relative to the bandit's. The best way to do this is to get the nose up as high as possible while rolling toward the overshoot direction. The altitude gained can become turning room exclusively available to the higher fighter. When combined with a 3/9 advantage, this may allow a reversal of roles.

4.3.10.5.7.3. Very Low LOS Overshoot. For very low LOS overshoots with HCA and range largely under control, it is probably wiser to keep turning hard in the same direction, unless rapidly losing the altitude you will soon need to resume jinking. Continuing the turn may trap the bandit in lag, but also allow for multiple off-bore shots if still inside a missile WEZ. If rapidly running out of “vertical,” a reversal with the same intent as discussed in **paragraph 4.3.10.4.6**, Choosing the Battleground, is warranted.

Figure 4.38. Capitalizing on Overshoots.



4.3.10.5.7.4. Low LOS Reversal Execution. As the bandit's flight path (due to closure/HCA problems your jinks generated) begins to slide past your 6 o'clock, immediately begin a wings-level (relative to the horizon) pull while selecting full AB and closing the speedbrakes. As your nose gets up above the horizon, begin to lean your Lv toward the bandit. If the bandit stays level, you rapidly move behind the 3/9 line. A roll to Lv-in-lead should allow a quick transition to offensive. If the bandit also pulls vertical, it will result in either a scissors or a stack. ***WARNING***: If the bandit has adequate 6 o'clock range available, your roll to wings-level may be all that is needed to solve the bandit's problems. Make a careful prediction of the bandit's turn radius potential prior to initiating the reversal. If in doubt as to the wisdom of reversing, do not do it. Keep your tight turn coming, realizing that the bandit will probably be back into guns in another 90 degrees of turn or so (as before "choosing the battleground" applies if altitude loss is critical). That, however, will be 10 seconds more you have ***lived***, and you have already proven that you can beat gun/missile attacks. Keep it up, keep sight and ***never give up***!

4.3.10.5.8. Reversal Follow-Ons. The end result of a reversal will be a status quo (still defensive), an offensive advantage or lastly, a neutral position. The defensive and offensive positions have already been discussed; the neutral position is broken down into two broad categories, scissors and stacks.

4.3.10.5.8.1. Flat Scissors. Scissors can manifest into two basic descriptions, flat and rolling. The defender executing an in-plane pull towards the defender, and the attacker responds in kind typically enters a flat scissors. The optimum execution to gain an offensive is to drive the adversary out front of the 3/9 line. The sight cue desired is seeing yourself get farther behind the adversaries 3/9 line, and the adversary getting farther away from your 3/9 line in each pass. LOS ***rate*** is not a good indication since the offensive adversary will stay behind your 3/9, the defensive adversary will remain close to your nose, and if neutral the adversary will transition down your 3/9 line from side to side. As the LOS rate stabilizes, ***unload***, and use full aileron and rudder to reverse the direction of pull. At airspeeds below 330 KCAS, use full AB to generate the greatest rate (radius is essentially the same). Continue these turn reversals until there is less than a turn radius between the two aircraft (neither aircraft can point at the other). At each pass the HCA will probably decrease. As soon as you see that you do not have enough range to point and employ ordnance, even if the adversary rolled out, transition to the vertical. Simply pull straight up instead of back at the adversary. This pull to the vertical is in full AB, wings-level, pulling to create a LOS forward now that you are not pulling towards the adversary. This will result in some kind of stack that is discussed in **paragraph 4.3.10.5.8.3**, Stacks.

4.3.10.5.8.2. Rolling Scissors. A reversal pulling to the high or low six of an attacker is the typical entry to a rolling scissors. In this case a LOS rate towards your nose is an indication of this maneuver working—keep it going. If there is a LOS rate aft, change up to an alternate plan quickly (prepare to jink). The situation where there is little to no LOS is the establishment of a rolling scissors. The key to winning this situation is to be the first one out. Change the pull direction to straight up as your wings are coming level. Pull to the vertical as previously described. If this maneuver is properly executed, the adversary is currently nose low and will flush out front. If you wait even one extra roll the adversary could stop it when he is nose high. A stack will normally result.

4.3.10.5.8.3. Stacks. Stacks are a result of some type of reversal and an important aspect of defensive BFM skills since they are a desired sub-objective of survival. Keep in mind, slow speed fighting may be a required skill to kill and survive. The inexperienced in slow speed fighting may experience the Darwinian principle. Although in a multi-bogey environment and the off-boresight capability of modern missiles, this area is extremely high risk in terms of vulnerability. A stack may be the only solution to winning a one-on-one though and should be thoroughly understood.

4.3.10.5.8.3.1. Side-Side Stacks. Side-side stacks typically result from a flat scissors or a gunshot overshoot, where the adversary has already closed the range to less than a turn radius as the defender starts the reversal. The desired result is to see forward LOS from the adversary and gain an offensive advantage. Resist the urge to pull towards the adversary, unless necessary to close the range down to get inside a minimum range for off-boresight ordnance. If necessary to close the distance, tap the rudder slightly to get the nose tracking in the desired direction. Any dipping of the wings will lose lift, and generate a faster rate along the ground, which pushes you forward on the 3/9 line. As the adversary floats out front, use a power reduction, dip the nose to employ ordnance, and complete the offensive transition. If the adversary gets behind you then a transition back to defensive principles is in order. Otherwise this side-side stack will remain until the aircraft runs out of fuel, a supporting fighter decides the fight, or you mismanage the aircraft and fall off first turning this fight into a vertical stack.

4.3.10.5.8.3.2. Vertical Stack—Low Man. Being the low man in a high-low stack is a very desirable position if you started out defensive. Minimize the altitude difference between the two aircraft. Attempt to get directly below and out of sight of the adversary. Any attempt by the adversary to check on your position will result in wing dips, losing lift, and generating forward LOS. Staying within 1,000 to 1,500 feet vertically is generally a safe place to deny the necessary turning room to an adversary. If unable to get that close and the adversary attempts to roll down towards you; there are several steps to take. First, pull to the adversaries belly side to make him dump the nose as much as possible. Second, get out of the way of any bullets coming your way. Third, after you have survived this attack, analyze how the adversary is falling off. If the adversary is attempting to leave or keep falling away, a quick transition to the offensive is available. If the adversary is stacking below you, the high ground is now owned by you, which may be a good thing.

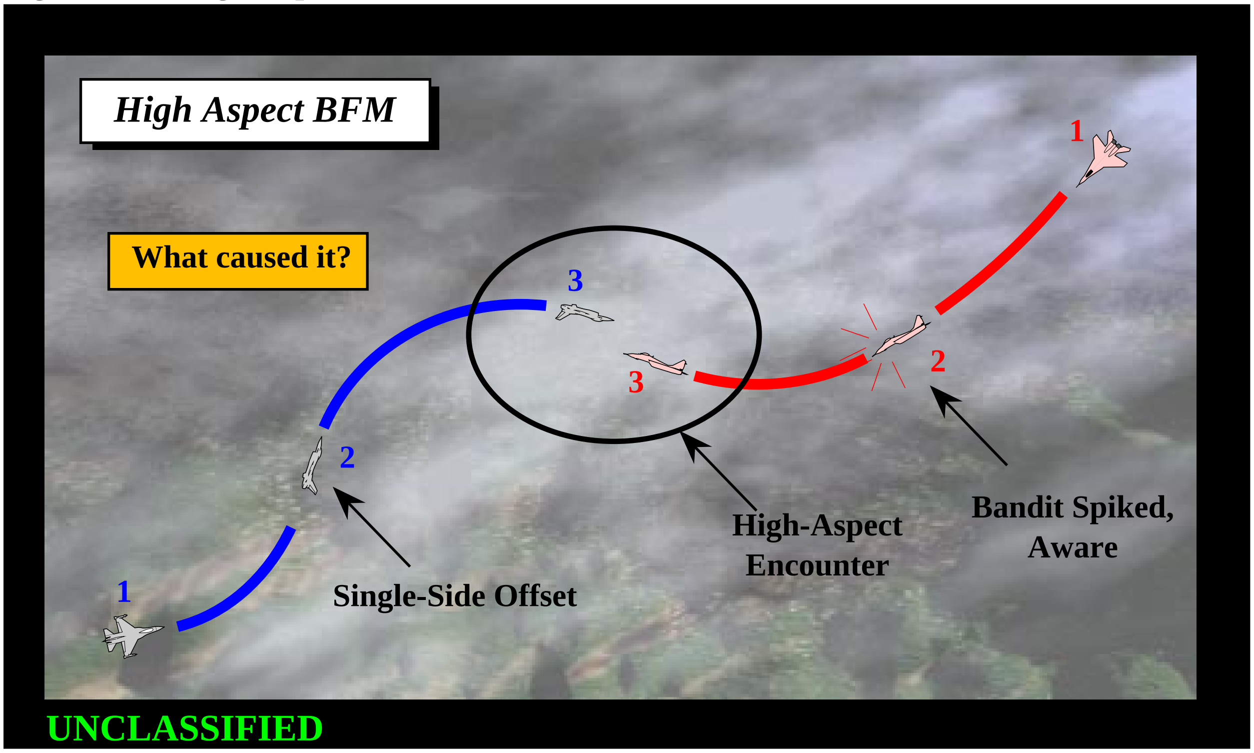
4.3.10.5.8.3.3. Vertical Stack—High Man. Being the high man in a vertical stack is a desirable position as long as you can survive there! Typically a full AB, slow LOS and rate platform is the target presented to the adversary. If you get within the off-boresight/missile capability, you may be a sitting duck! Assuming the aircraft is not in a WEZ the optimum plan is to get enough turning room to covert to an offensive position. If you find yourself out of a WEZ, and neutral, you have achieved a temporary objective of immediate survival. Work to get 2,000 to 3,000 feet of vertical altitude difference directly above or behind the adversary. There are a variety of ways to transition to a WEZ: a barrel roll, slide down with a power reduction, lastly a nose pushover. The barrel roll and power reduction are the easiest to execute but require slightly more altitude advantage than the nose over. Simply fly to a position where you can employ ordnance, typically the gun. Ensure you have enough range to shoot and avoid the fireball or bubble. The nose over is slightly more complicated and should not be attempted for the first time in the middle of a BFM training sortie. From a nose high, just above the low speed warning horn airspeed, pull power to idle while pushing forward on the stick. The aircraft will pitch over rapidly with a minimal loss of altitude, and even sometimes gain altitude. Set the gun cross in lead, not much is required at slow LOS rate, take the shot and ensure you will avoid the fireball or bubble.

4.3.10.5.8.4. Vertical Transitions In-Close. Proper recognition and execution in the extremely dynamic vertical fight is another critical element of slow speed fighting. As the high fighter coming down correct power selection is critical. If you will force the adversary to fall off then idle/speedbrakes is the best. If the adversary is staying in the nose-high position an AB setting allows for resetting the stack after your attack. The low man needs to determine how best to take advantage of the high man falling off. This concept also comes into play in the vertical fight when one aircraft is overshooting in the vertical. At the pass, determine if the adversary is falling away and start a vertical lead turn as LOS rate passes your nose (the adversary is giving you the necessary range to prosecute an attack). If the adversary is attempting to keep the range close by rolling underneath you, a continued nose-high position to get range is the optimum plan. The concepts of offensive and defensive BFM are intertwined in the complex scenario of high-aspect BFM.

4.3.11. High-Aspect Basic Fighter Maneuver. Normally Vipers arrive at a high-aspect merge the same way as the offensive perch—from an intercept as shown in **Figure 4.39.,** High-Aspect BFM. The difference is that before you arrived inside a controllable position, the bandit detected you and turned to counterattack. This is not an unusual situation in the fourth-generation fighter environment. With increasing SA capabilities, expect to meet the bandit head-to-head. The mindset for success is to gain the offensive advantage and convert for a kill or to survive the attack by an advantaged fighter. The objectives of high aspect BFM are:

- Recognize and exploit advantages.
- Recognize and execute lead turns.
- Transition to offensive or defensive BFM if required.
- Ensure 100 percent valid shots, no missed opportunities.

Figure 4.39. High-Aspect BFM.



4.3.11.1. High-Aspect BFM Essentials. High-aspect encounters seem to be the largest source of energy management misconceptions. To appreciate the role of energy after a high-aspect merge, understand the basic physics of turning, turn directions, fight driving, while recognizing the pictures you would see in a fight where both contestants match each other foot-for-foot in altitude, and degree-for-degree in angle. This is an important because it defines whether you are winning or losing the turn prior to the next pass. It also defines the controlling position for a superior capability airframe when the fight starts. To plan at the next pass, recognize as early as possible whether you are winning the turn (gaining angles to keep at the pass), losing (the bandit gains and maintains for use at the pass), or breaking even (a 180-degree HCA at the pass). Altitude differences play an important role in this maneuvering since one contestant can give up some vertical to keep up in the horizontal angle race, and likewise, a higher bandit can use the altitude advantage to enhance turn rate to arrive at the pass with angular advantage.

4.3.11.1.1. Turning Room Prior to 3/9 Pass. In high-aspect confrontations, generally look at the area forward of the 3/9 line as a place to find turning room. Turn room is only gained under two conditions: the adversary lets you have it by being unaware of your presence; and the adversary is ignorant of the visual fight basics. (See **Figure 4.40.**, Turning Room Prior to 3/9 Pass.) If the bandit does not allow you to have turn room, you will not get it. If you try to get it prior to the pass by holding the nose off until the pass, you will be unable to take back the angles given away at the pass and will have, in effect, given the bandit a lead turn opportunity. In the initial two passes of any high-aspect fight there are usually few opportunities to take advantage of a classic lead turn. From the first turn through the second pass, advantages are evened out by Tc shrink and average turn rate. The fighter who seeks to win it all in the first two turns is going to be in for a big disappointment. Wait! The bandit is liable to err in your favor at any time. Unilateral turn room for your lead turn comes later in the fight when the bandit arrives at a performance limit.

4.3.11.1.2. Positioning for the Merge. Positioning for the merge is often overlooked during high-aspect fights. Merges generally develop in one of two ways:

4.3.11.1.3. Bandits that can actively maneuver pre-merge will force option number one. Constrained or unaware bandits will allow you option number two. The concept that a lead turn is always available stems from a belief that the other aircraft cannot turn well. This "poor turning" can be caused by excessive airspeed, low altitude restrictions, or anytime the bandit is on a performance limit. Assessing where a limit may exist and then exploiting it requires careful intelligence study and absolutely solid knowledge of energy physics. (See **Figure 4.41.,** Positioning for the Merge.)

- The two players will arrive level at the merge and 180 degrees HCA and as close in lateral distance as the training rules will allow.
- One player will begin what appears to be a "lead turn" prior to the pass.

4.3.11.1.4. Effect of Spacing at the Merge. The well-planned fight begins here. The chosen fight entry will influence the bandit's turn direction and the bandit's pre-merge choices will influence yours. As two fighters pass with 180 degrees AA the horizontal distance between them is a piece of their Tc during the next turn. If they turn toward each other, the distance is inconsequential. If one chooses to turn away from the other, the distance becomes excess radius that must be overcome prior to the next pass to avoid being defensive. A fighter who wants a two-circle fight should seek as much horizontal offset as possible to drive the bandit to turn two-circle. If the bandit chooses to disregard the problem, the fighter will enjoy a significant advantage after the 180 degrees in the ensuing one-circle fight. (See **Figure 4.42.,** Effect of Spacing at the Merge.)

4.3.11.1.5. Effect of Position on Angles at the Merge. Angles at the pass work in the same manner. A fighter with an angular advantage at the pass also influences the bandit to turn toward the fighter to negate it. If the bandit chooses to reverse direction, the amount of advantage at the next pass is a direct function of how far aft of the bandit the fighter crosses the extended 6 o'clock line. Remember, offset is meaningless prior to the pass against an aware bandit. As long as the bandit allows it, it will work as described. Altitude Delta at the pass is additional energy for the high fighter. This is usable as extra P_S against the lower fighter. In terms of energy, the only altitude that matters is that between the adversaries. (See **Figure 4.43.,** Effect of Position Angle at the Merge.)

Figure 4.40. Turning Room Prior to 3/9 Pass.

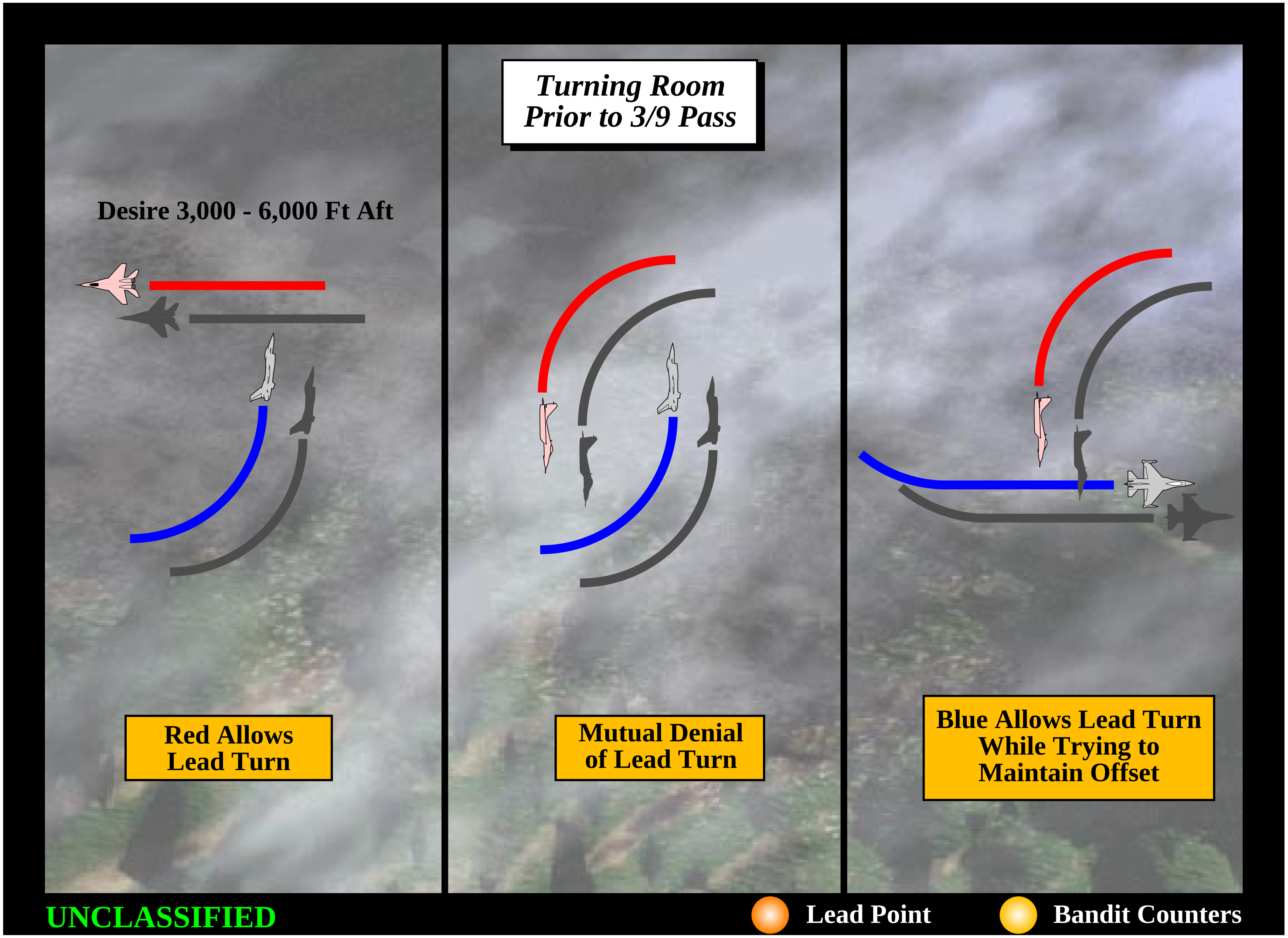
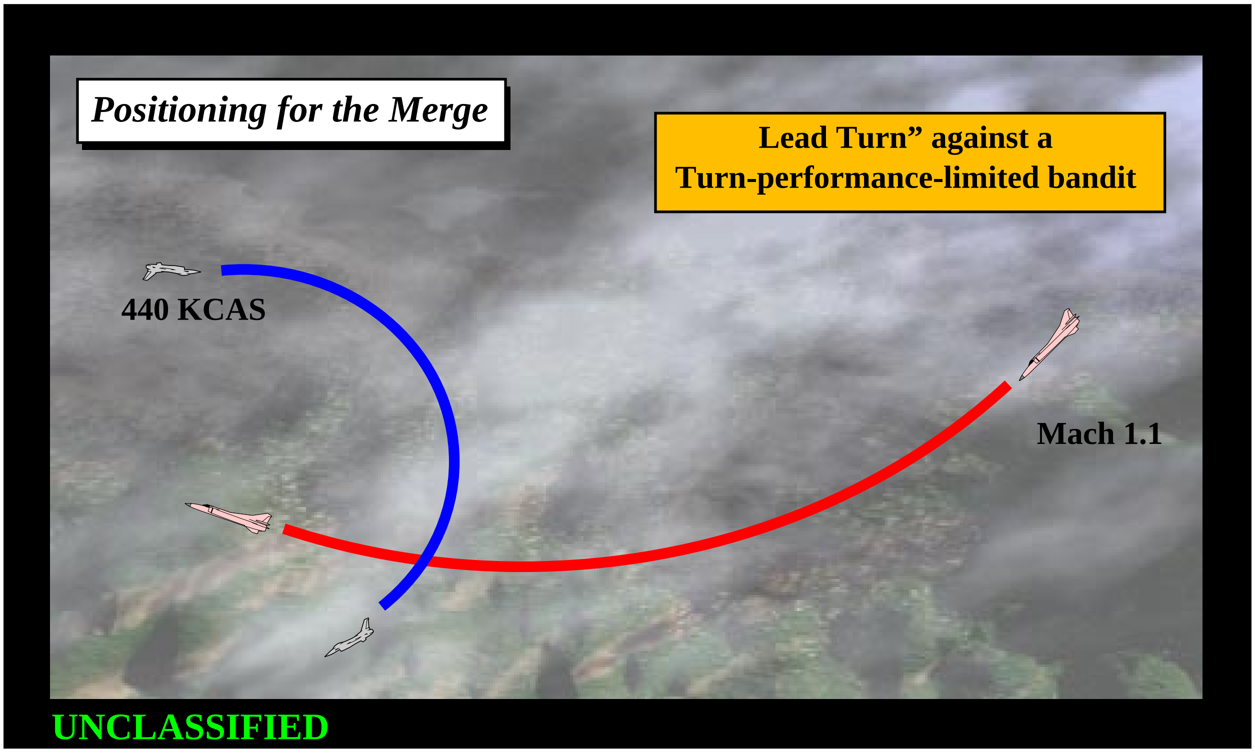


Figure 4.41. Positioning for the Merge.



4.3.11.1.6. Optimum Starting Point for Single-Circle Fight. The turn you cannot influence by position is the single-circle fight. (See **Figure 4.44.**, Optimum Starting Point for Single-Circle Fight.) The best you can do is negate any radius offset by zeroing it out. This does not mean scraping paint. Passing directly above or below the bandit and start turning in the horizontal. If the desired fight is single-circle, arrive at the pass from below. This affords maximum visibility while forcing a loss of sight for the bandit at the pass. At 3/9 the bandit can turn either way (so can you) with negligible effect. Influence the bandit to start the turn early to keep sight, and have the last word by staying visual throughout the pass. The last one to turn sets single-circle geometry.

4.3.11.1.7. Which Way to Go. The direction of the turn at the pass defines what advantages the fighter will seek to exploit in the ensuing turn. (See **Figure 4.45.**, Which Way to Go.)

Figure 4.42. Effect of Spacing at the Merge.

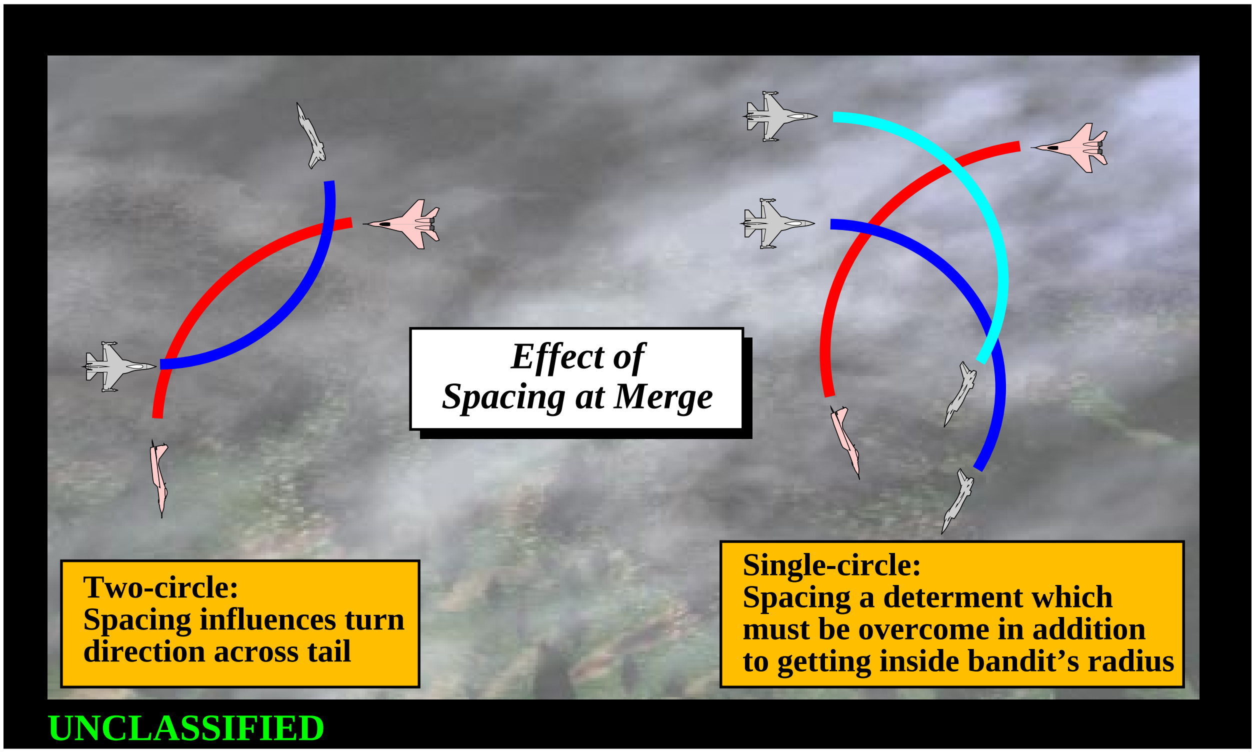


Figure 4.43. Effect of Position Angle at the Merge.

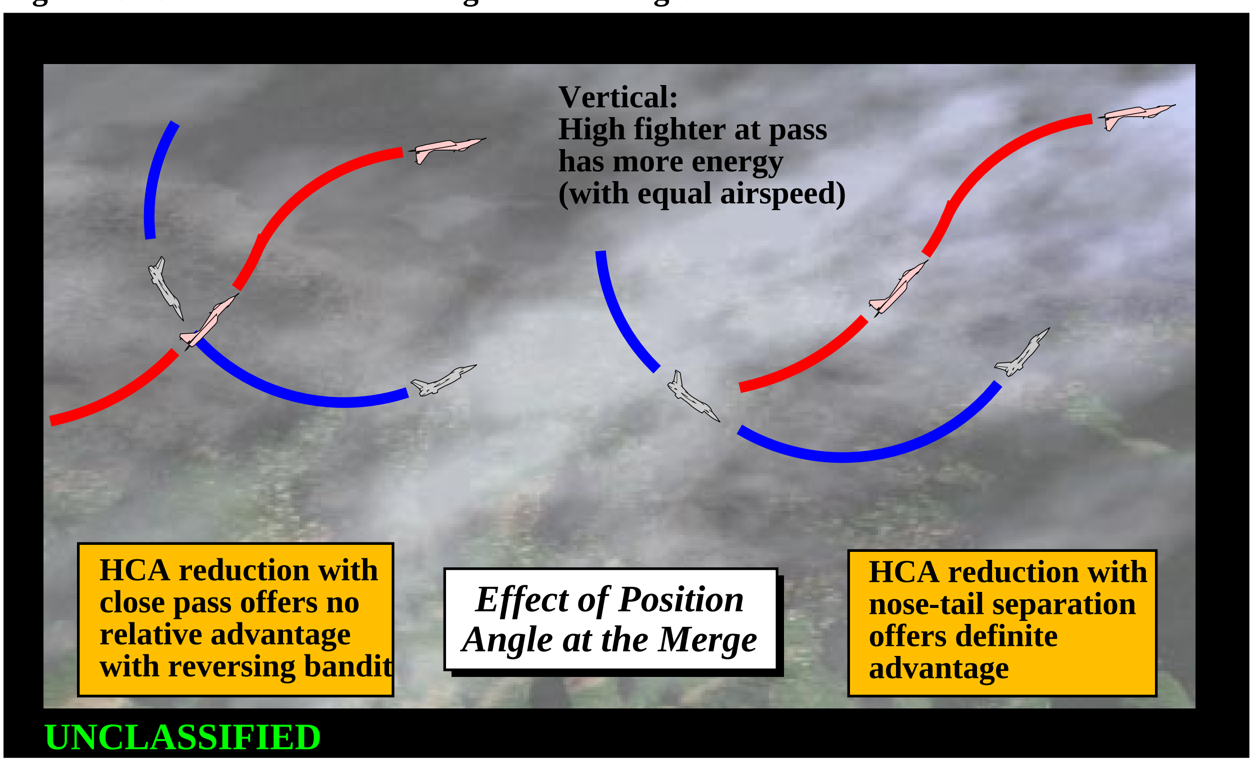


Figure 4.44. Optimum Starting Point for Single-Circle Fight.

OPTIMUM STARTING POINT FOR SINGLE-CIRCLE FIGHT

- **OPTIMUM STARTING POINT FOR A SINGLE-CIRCLE FIGHT IS BELOW THE BANDIT (NO LATERAL OFFSET)**
  - **MAXIMUM VISIBILITY – BANDIT HAS TO "COMMIT" FIRST**
  - **ALLOWS FIGHTER TO INSTANTLY ADJUST FOR BANDIT TURN OR CHANGE IN TURN DIRECTION**

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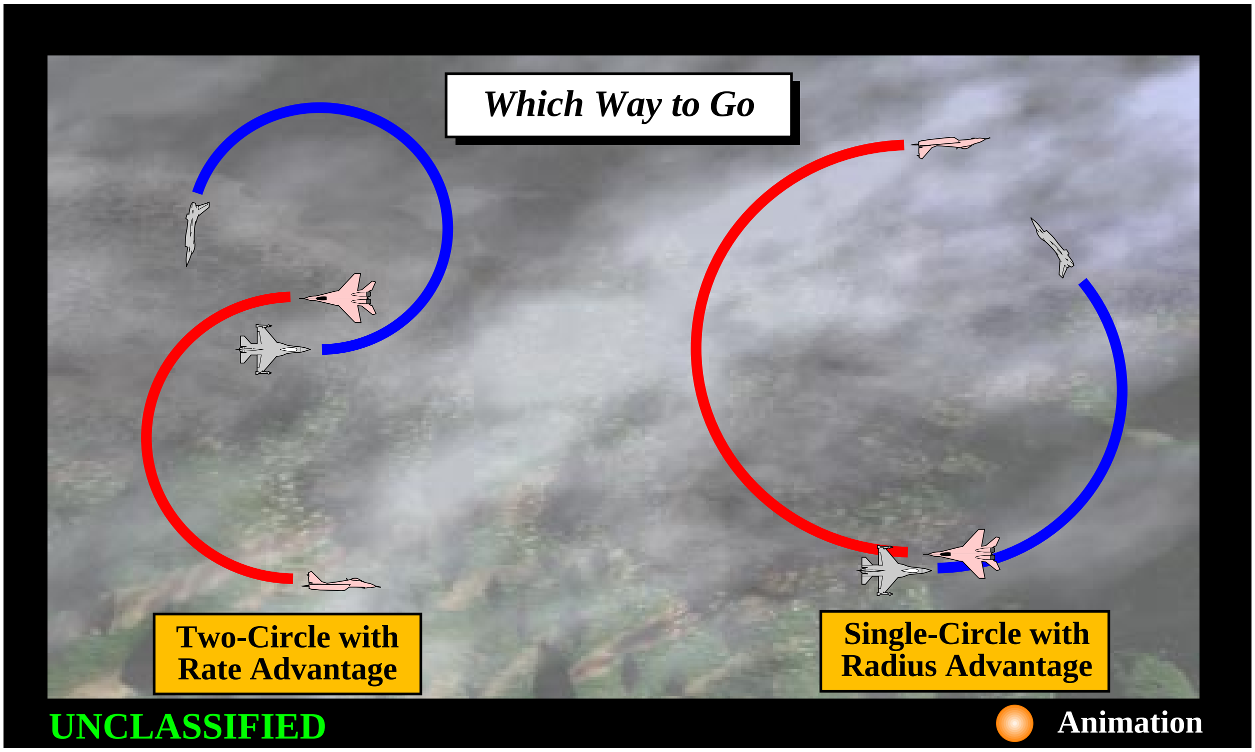
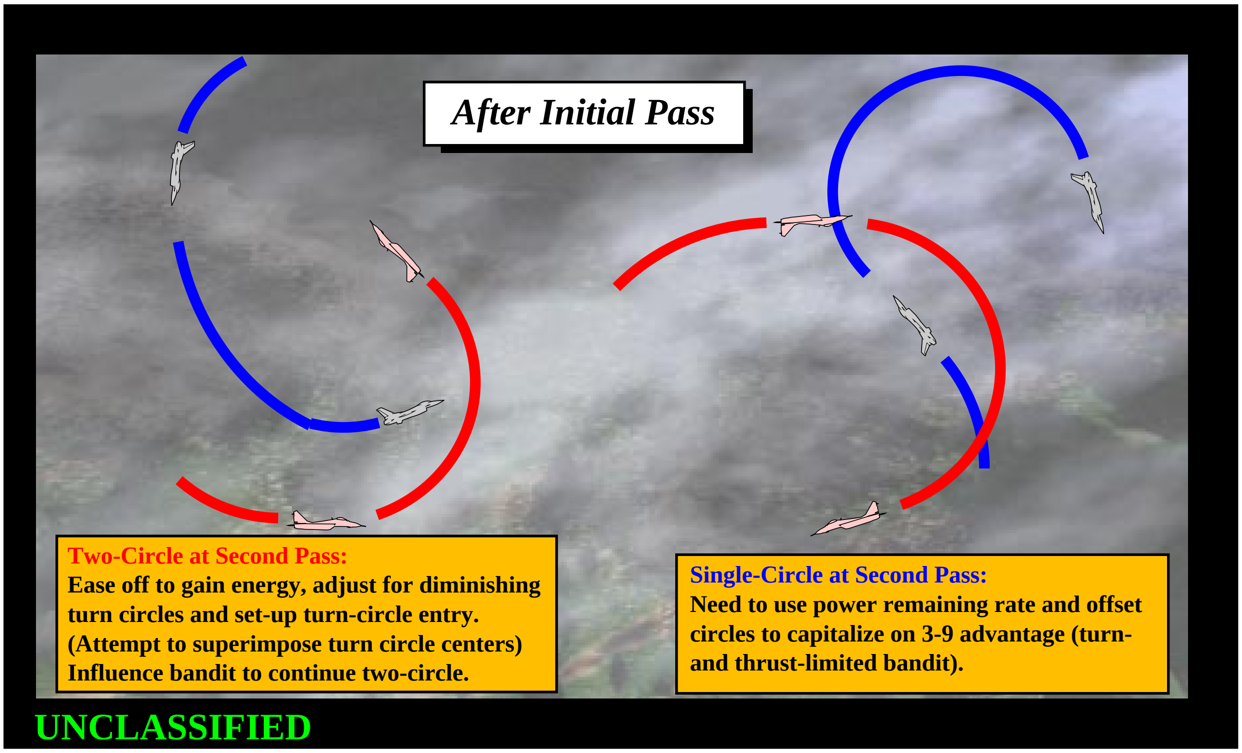
Figure 4.45. Which Way to Go.



4.3.11.1.7.1. Two-Circle. In this case both fighters turn the same way (bandit and fighter turn across each other's tails) and are trying to utilize superior turn rate. A positive Delta in rate will allow angles that reduce HCA and increase offensive posture at each pass for the fighter. Rate alone does not win the war. As you recall from offense, turn rate for the Viper is highest when crossing over the hump on the turn performance chart. It would seem logical that this is where you would want the fight to occur. Start fast and use the excess turn rate available, while maintaining above the maximum rate airspeed. Just like offense, drive the bandit down the lift limit line first and follow the bandit while reducing AA and HCA.

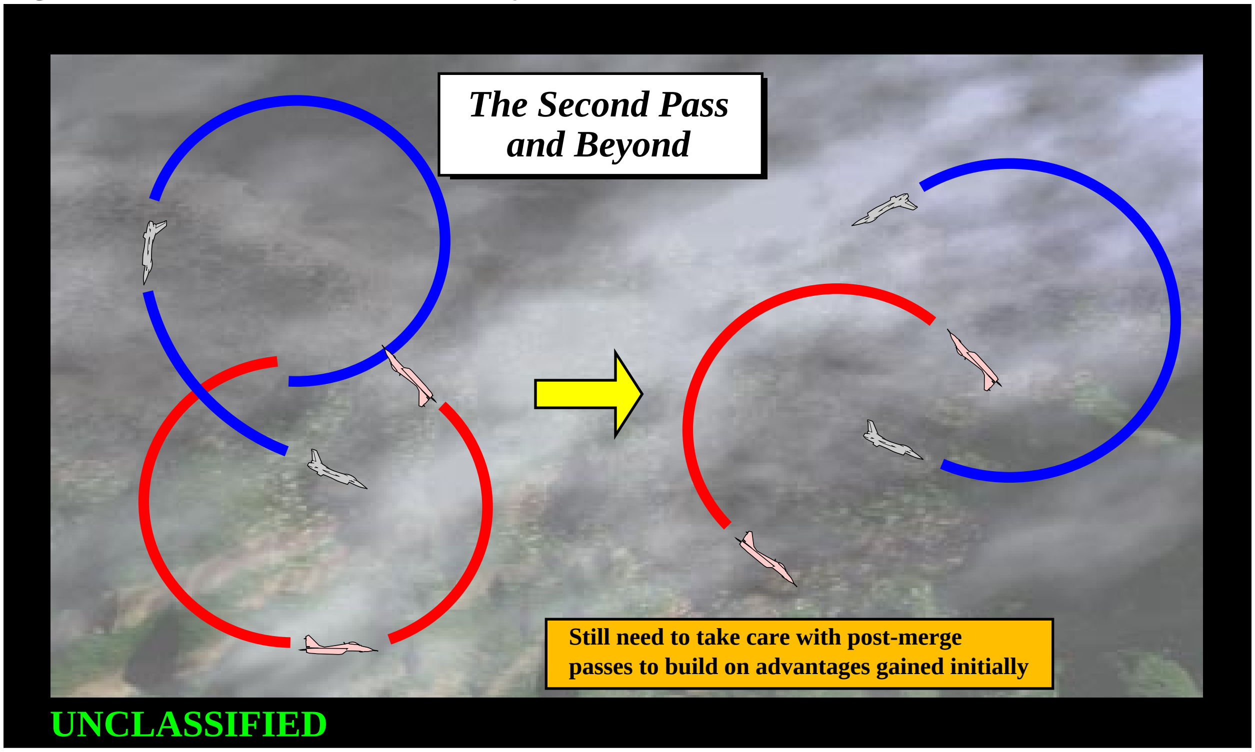
4.3.11.1.7.2. Single-Circle. In this case the second fighter to turn turns away from the other's tail. In the single-circle fight, turn rate advantages are nearly inconsequential. The deciding advantage in the follow-on pass will be based on turn radius. The aircraft with a smaller radius can point at the other and will generate an advantage in HCA at the pass if the turn is reversed (two-circle transition). In **Figure 4.46.**, After Initial Pass, shows the utility of this advantage depends on the fighter's ability to reestablish a positive rate Delta or the ability to continue capturing range aft of 3/9 by maneuvering if the bandit reverses his turn direction. If the fighter chooses to keep the turn going in the same direction at the pass after gaining advantage, the advantage is lost in the next 180 degrees and the advantage is given away if the bandit reverses turn direction.

Figure 4.46. After Initial Pass.



4.3.11.1.8. Effecting Bandit Turning. If there is any discussion at all about merge position entry, it certainly never gets applied to the later passes in the fight where it is even more critical. (See **Figure 4.47.**, The Second Pass and Beyond.) Each pass in the fight is an opportunity for the players to switch up the character of the fight from one- to two-circle or vice versa. For a fighter trying to play out a game plan in a particular fight, subsequent passes are where the plan will likely go up in smoke. Put some influence on the bandit to turn in the desired direction. Merge entry is the same with each subsequent pass being a new merge to enter. Set objectives to be achieved prior to the next pass and set up the bandit to turn the way you want. The same principle for influencing one- and two-circle fights apply regardless of energy state. It will be of utmost importance to understand the boundaries when switching up the game plan.

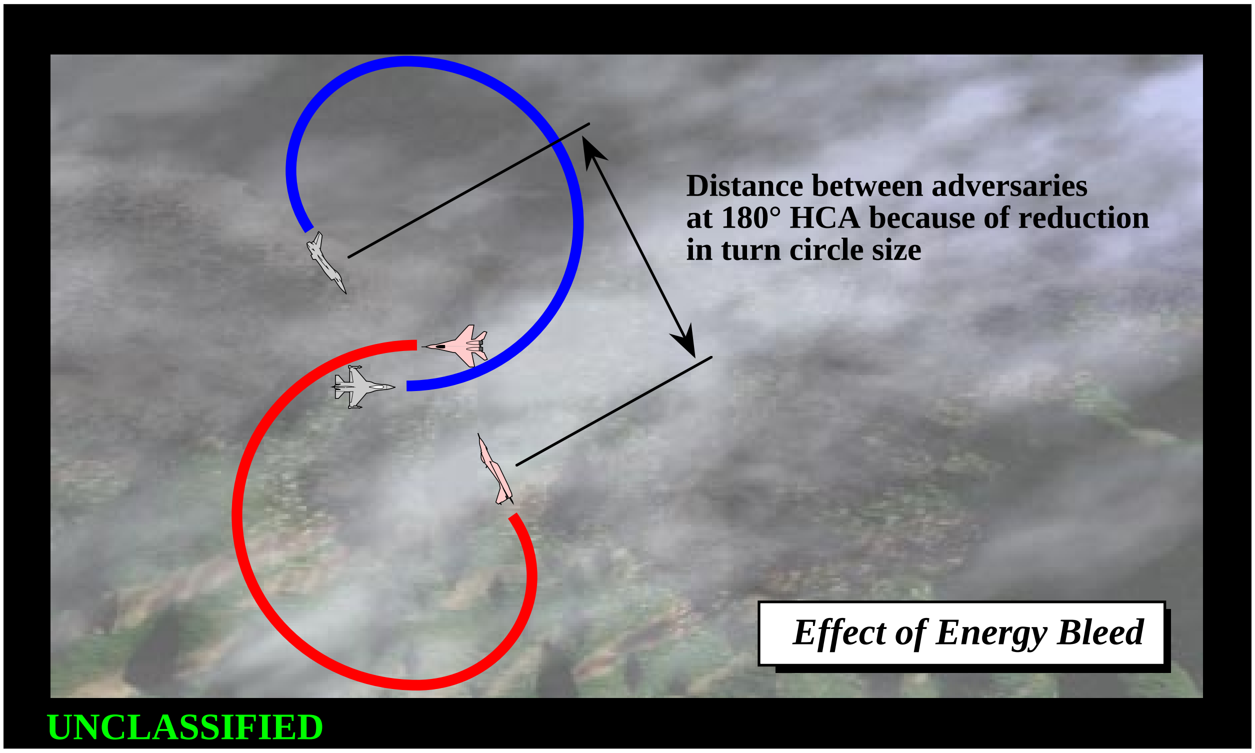
Figure 4.47. The Second Pass and Beyond.



4.3.11.1.8.1. Radius Effect During Two-Circle Fight. The radius effect of hard maneuvering from a high initial energy state as adversary's turn to gain advantage is termed "Tc shrink." As a fighter turns 180 degrees on the aft limit and goes from 450 to 250 KCAS the radius starts at 3,200 feet (450 KCAS at 9 Gs), and 45 degrees of turn later is at 2,500 feet (400 KCAS at 8.3 Gs). The aircraft does not turn around the same point throughout the turn. The center moves away from the starting point towards the fighter. Halfway around the turn the radius is 2,200 feet (7.7 Gs at 350 KCAS). At the completion of the 180 degrees, the fighter is pulling 4.3 Gs at 250 KCAS with a radius of 1,800 feet. In the turn the fighter reduces to 55 percent of the original speed and 59 percent of the original radius.

4.3.11.1.8.1.1. Put an adversary doing the opposite in a two-circle fight and it becomes apparent that the fighter must ease off and drive to the bandit when coming out of the first turn. This may not be the way to fly the turn—only a discussion of limiter turn physics. An example is shown in **Figure 4.48.**, Effect of Energy Bleed.

Figure 4.48. Effect of Energy Bleed.

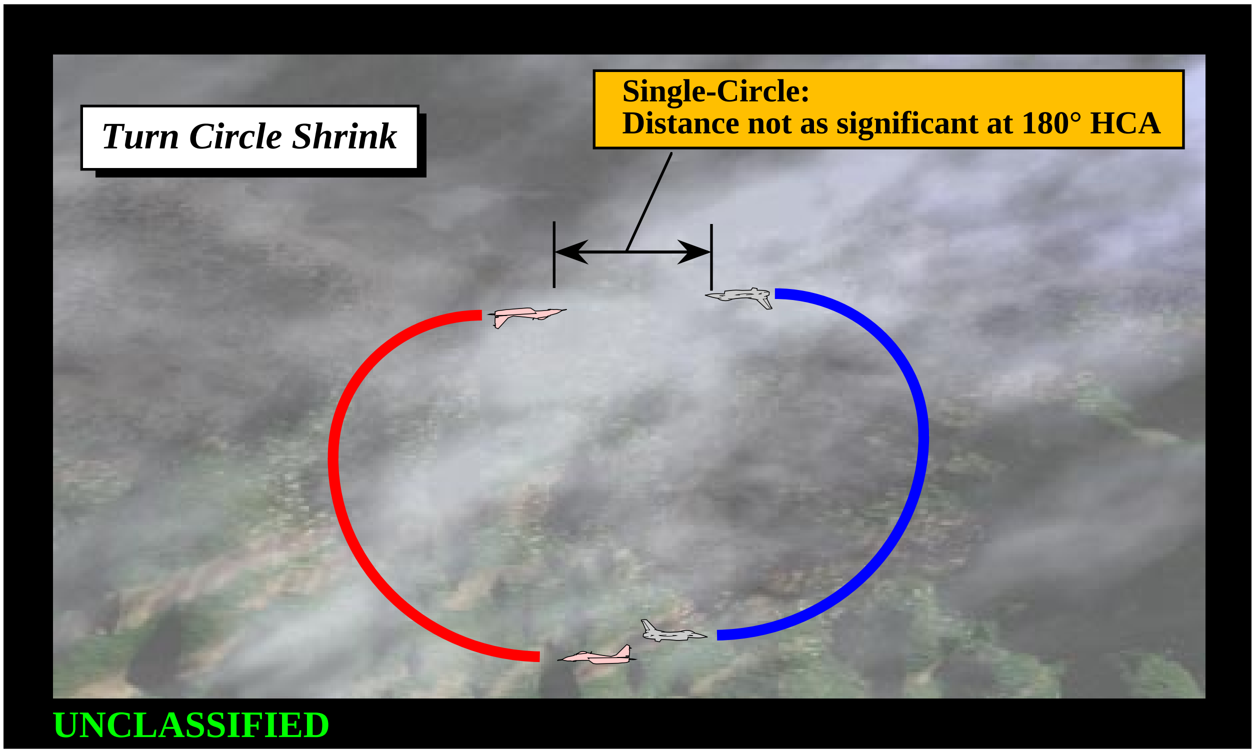


4.3.11.1.8.1.2. In a single-circle fight the same thing happens, but the range between the fighters after the 180 degrees is a lesser amount. The spread between the two adversaries is hundreds of feet versus thousands in a two-circle. (See **Figure 4.49.**, Turn Circle Shrink.)

4.3.11.1.8.2. Matched Pursuit. The first picture to measure status happens at the merge.

4.3.11.1.8.2.1. If two fighters pass in completely neutral geometry (i.e., co-altitude, have 180 degrees HCA, and turn simultaneously toward the same cardinal direction while holding each other on the horizon), the next assessable picture occurs as the bandit crosses the fighter's 3/9 line across the circle. The bandit views you through his 3/9 line as you view the bandit’s aircraft on your 3/9 line approximately one diameter away. At this point both are pointed in the same compass direction with 0 degree HCA and level on the horizon.

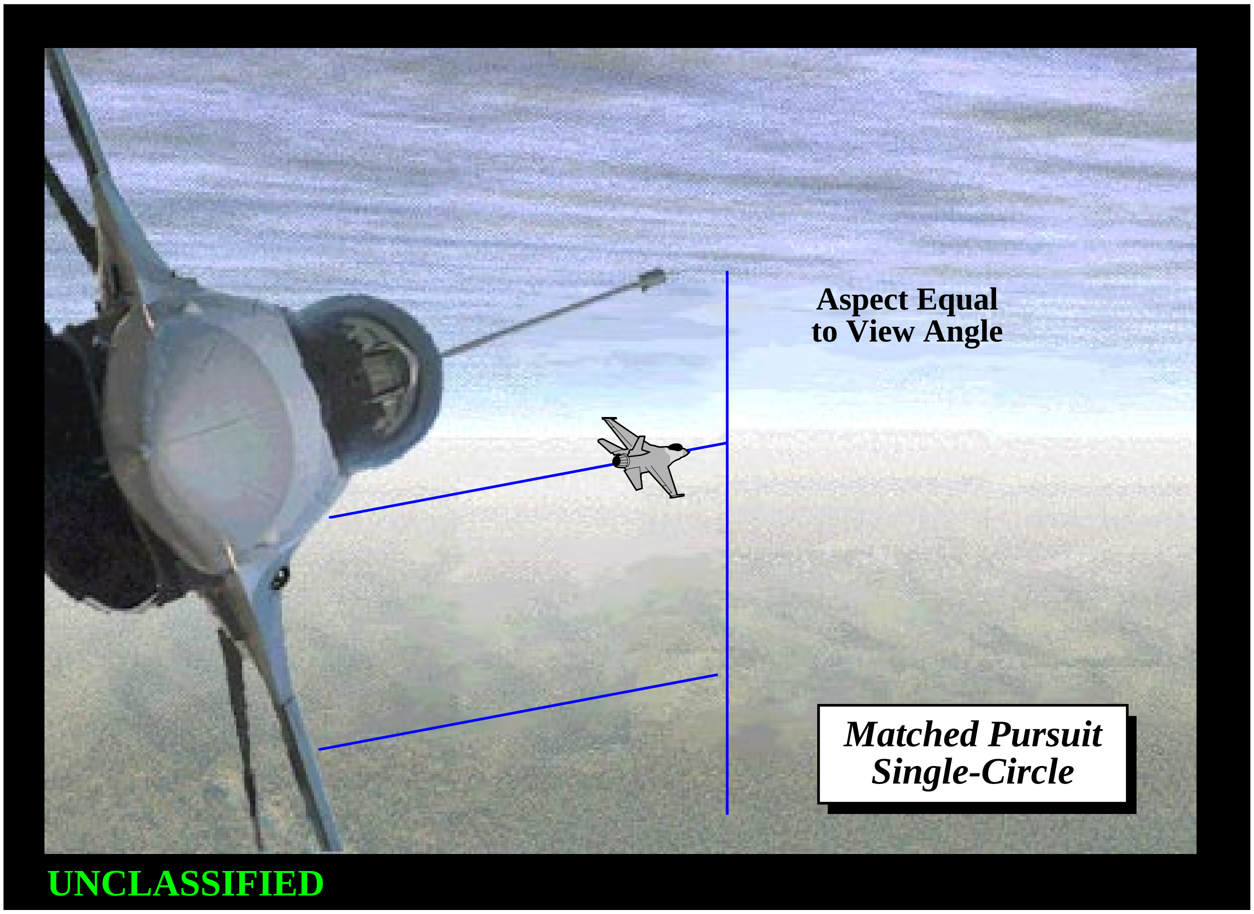
Figure 4.49. Turn Circle Shrink.



4.3.11.1.8.2.2. The turn remains matched degree-for-degree and foot-for-foot—completely neutral in geometric terms. (See **Figure 4.50.**, Matched Pursuit—Single Circle.) The key indicators of matching are bandits on the horizon, and both fighter and bandit view each other through equal AA as aspect climbs to 180 degrees. Each fighter turns 180 degrees to the next pass and because of energy bleed off and Tc shrink (brought about by reduction in airspeed and hence turn radius), the fighters end up in the final position of equality—nose-to-nose on the horizon with 180 degrees HCA. No angle or elevation advantage is gained by either fighter, and the second pass occurs geometry and energy neutral—***neither is winning anything***.

4.3.11.1.8.2.3. In a two-circle fight the same cues are present through 360 degrees of turn (versus 180 degrees) but may be harder to determine due to the increased distance between the fighters. (**Figure 4.51.**, Matched Pursuit—Two-Circle.)

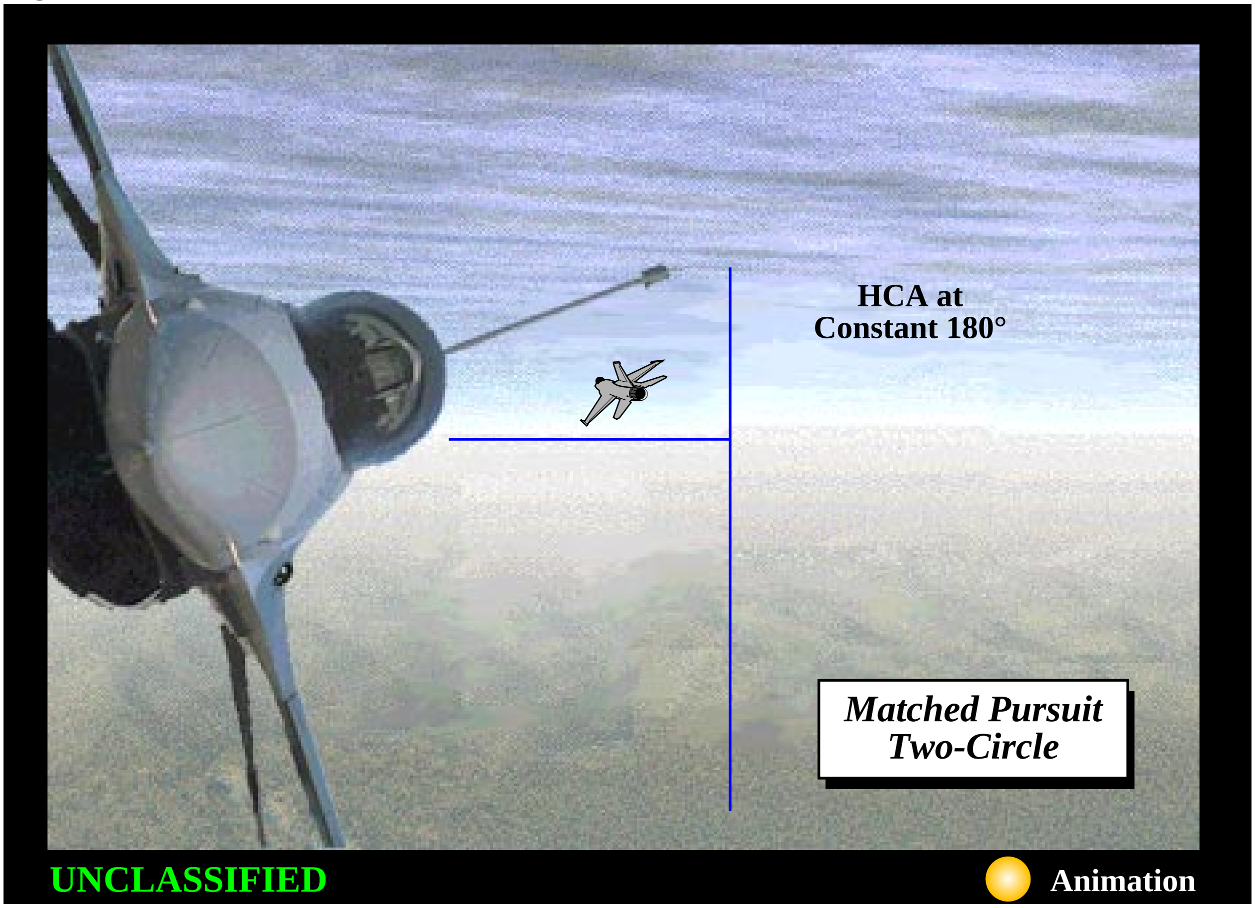
Figure 4.50. Matched Pursuit—Single Circle.



4.3.11.1.8.3. Winning Cues. To win turns in the horizontal, hold the bandit on the horizon with roll control and pull aft hard enough to make the bandit appear to lose the rate or radius contest. Convert it to a usable advantage at the next pass. To illustrate the winning picture, use three points in the turn: across the circle, just prior to the next pass, and just after the pass.

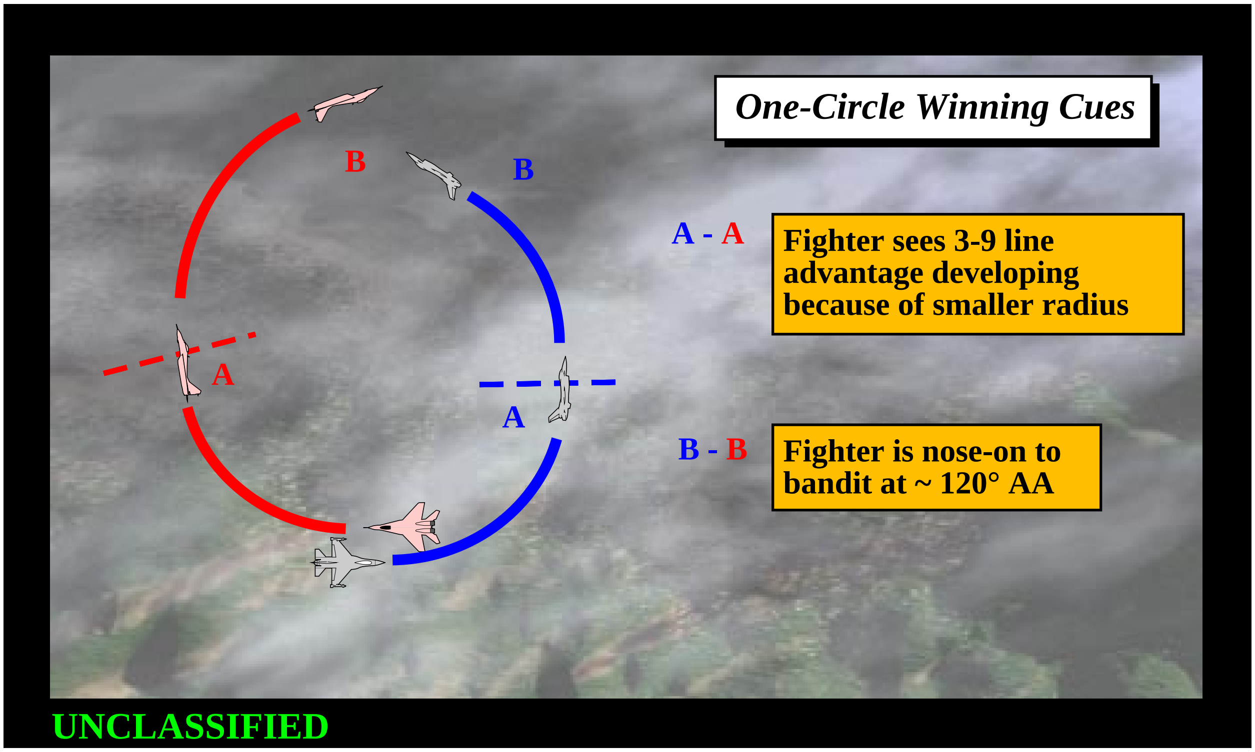
4.3.11.1.8.3.1. One-Circle—Winning Cues. In a one-circle contest, as shown in **Figure 4.52.**, One Circle—Winning Cues, the bandit that passes high aspect and starts to lose will show that across the circle after 90 degrees of turn. At this point, you will be looking out your 3/9 line and the bandit is looking back, aft of his 3/9. As the bandit finally pulls you through his 3/9, you will notice LOS begin across the horizon in the direction of the bandit's nose. ***NOTE***: this is not "canopy drift" but a drift on the horizon. All of the high-aspect pictures discuss drift on the horizon, not drift on the canopy. In each turn the bandit goes from 6 to 12 o'clock every time. Canopy movement is constantly dynamic and nearly irrelevant to assessing advantaged status. As the pass continues, notice the bandit LOS accelerates across the horizon as you point at the bandit's aircraft and close the range. This is the area to look at for exploiting an advantage.

Figure 4.51. Matched Pursuit—Two-Circle.



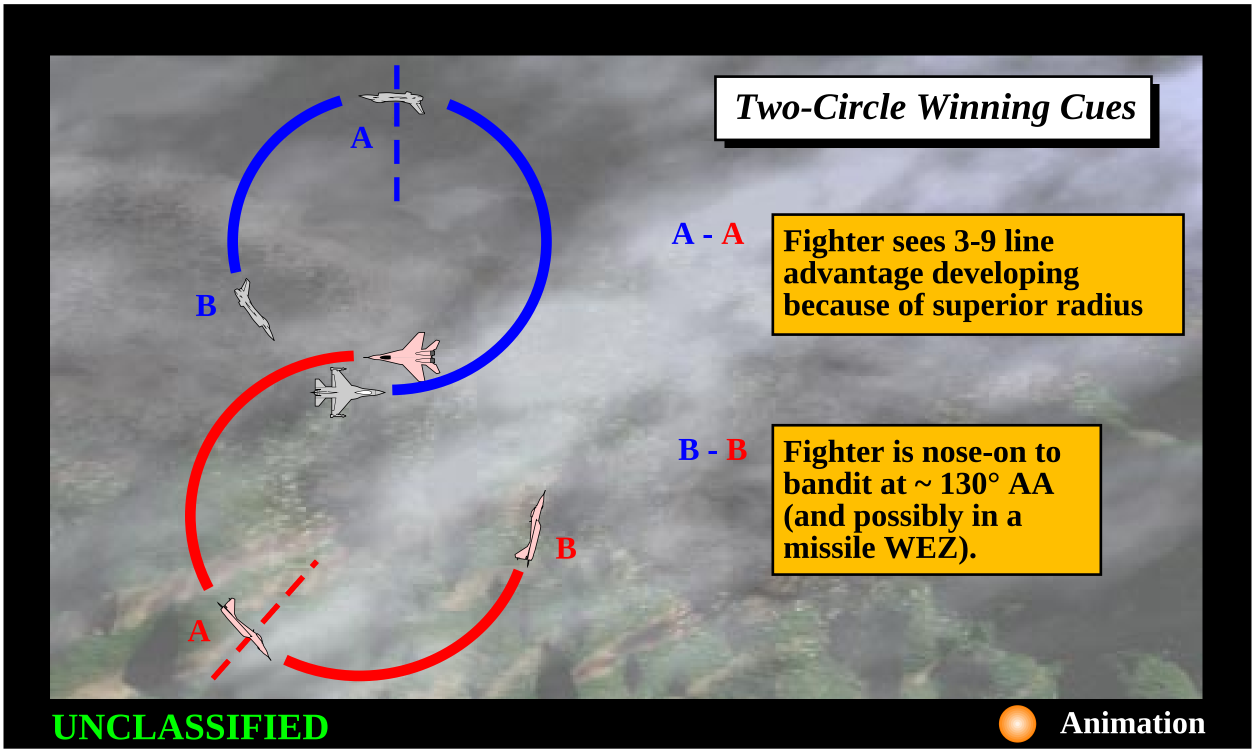
4.3.11.1.8.3.2. Two-Circle—Winning Cues. In a two-circle fight, as shown in **Figure 4.53.**, Two-circle—Winning Cues, the losing bandit will begin to lag in turn rate as the turn continues. As you turn to put the bandit on your 3/9 line, notice the bandit is looking back along a line aft of his 3/9. The LOS is irrelevant at this point; you are going opposite directions. The key indicator of advantage is from angle only and is difficult to see. As the turn progresses, you will be able to point at the bandit before the bandit points at you, and LOS in the direction of the bandit's nose will appear. Again, this is the area where the advantage must be exploited.

Figure 4.52. One Circle—Winning Cues.



4.3.11.1.8.3.3. Winning the Turn Vertically. Less capable bandits can present what appears to be a neutral fight in angles and hide lower capabilities for a short time. Eventually, the bandit will have to pay the P_S back by going down. A power-limited bandit uses this move to intimidate or mask airframe weakness. In this, the bandit slowly begins to drop below the horizon as the bandit overbanks to use the potential energy to maintain rate. At the next pass the bandit flies below the fighter without attempting to bring the nose back up to zero out the angles. Use this vertical Delta to enhance your position in angles. Keys to recognition—the bandit eases off the horizon and does not attempt to point at the pass. If the bandit rapidly departs the horizon and points at you from below; you probably have a game plan being used against you. If it is not countered early, you may give away significant advantage after the next pass.

Figure 4.53. Two-Circle—Winning Cues.



4.3.11.1.9. Lead Turns. Winning the turn does not win the pass. The proper pursuit course must be set up prior to the pass based on the angle advantage gained throughout the turn. (See **Figure 4.54.**, Second Pass Execution Two-Circle.) If the turn is continued to the pass, the fighter will not generate the WEZ range and the control position. Accomplish several steps at each pass to turn the angles gained into weapons range aft of the bandit's 3/9 line:

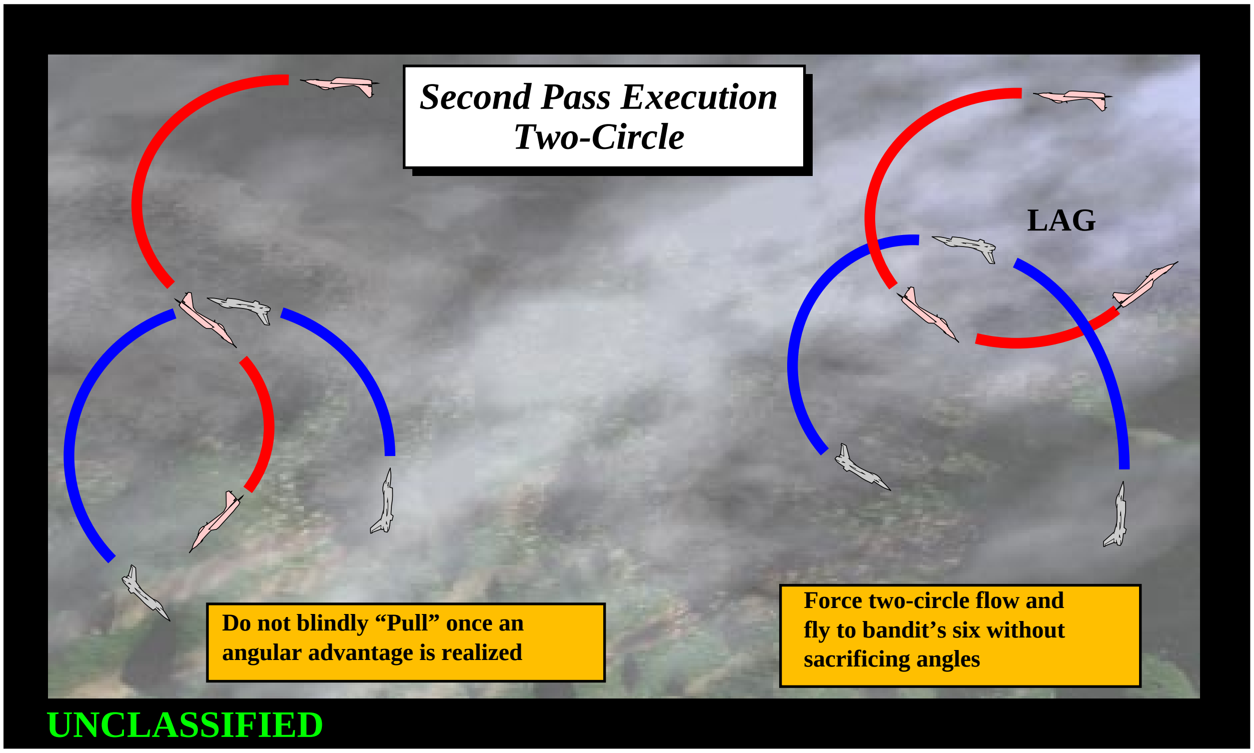
- Recognize the advantage as a lead turn opportunity.
- Fly the aircraft to the correct geometry.
- Start the turn prosecution to exploit the bandit's performance limit.

NOTE: The process differs from one- to two-circle fights depending on energy and follow-on game plans.

4.3.11.1.9.1. Lead Turning Against Rate-Limited Bandit. This scenario starts at the point left off in the two-circle winning discussion. (See **Figure 4.55.**, Lead Turning Against Rate Limited Bandit.) Then comes to the second pass with an advantage in angles (the ability to point at the bandit before the bandit can point at him). Recognize this advantage, but do not start lead turning. The geometry places the two-circle turn centers apart from each other by two radii. The fighter must move the Tc center nearer the bandit's to transition to gain a controlling position. The bandit is, by definition, on a performance limit because the bandit is losing the turn and cannot negate the fighter's plan (the bandit's Tc radius is as small as it is going to get, and the fighter is entering it offset from the nose). This limitation allows the fighter to collapse the turn center point toward the bandit's:

- Ease out of the turn pre-merge.
- Hold the bandit about a clock position away from the nose.
- Start the lead turn when the bandit's aircraft LOS rate accelerates rapidly along the horizon (not later than 180 degrees HCA).

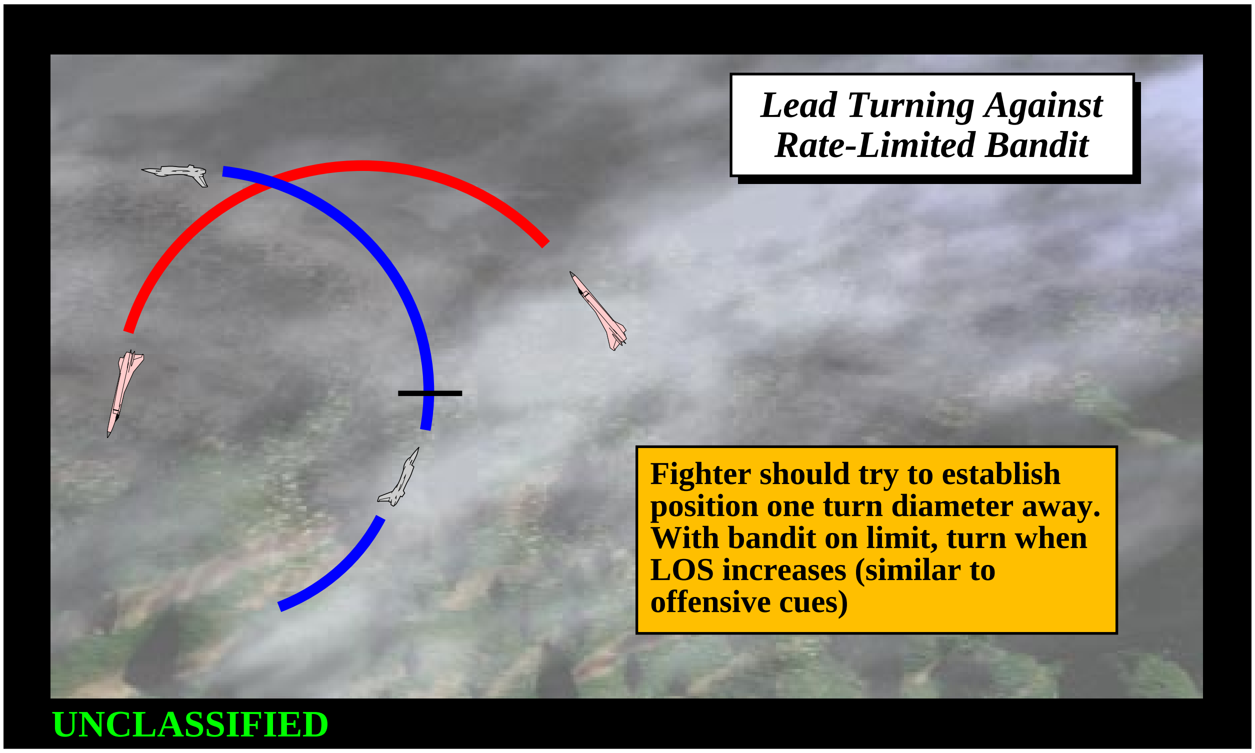
Figure 4.54. Second Pass Execution Two-Circle.



NOTE: The lead turn is a nose low, Lv-on, maximum pull to reduce HCA while passing aft of the bandit. Just like offensive pursuit, the best turn will be accomplished from a point slightly higher than the bandit as you approach. The fighter will see the winning picture and each subsequent pass will see the bandit at a lower aspect than the previous.

4.3.11.1.9.2. Lead Turning Against a Radius-Limited Bandit. Lead turning in a single-circle fight uses the same visual cues—the fighter sees an advantage. Advantage indicators are the fighter observes the bandit moving on the horizon, and in the same direction the bandit's nose is pointing. (See **Figure 4.56.**, Lead Turning Against a Radius Limited Bandit.)

Figure 4.55. Lead Turning Against Rate Limited Bandit.

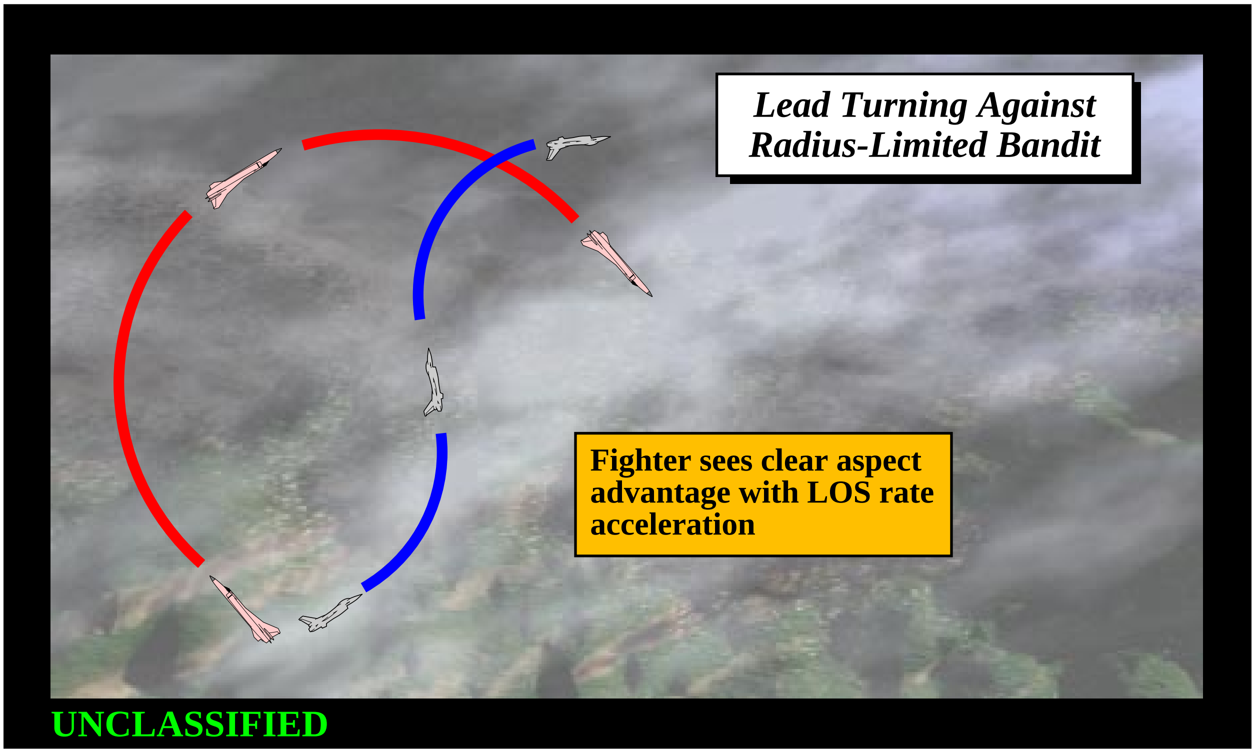


NOTE: The bandit is scribing a larger radius, and the fighter is inside the Tc. To capitalize on the pass, the fighter must reverse turn direction and execute the lead turn as the bandit's LOS rate accelerates on the horizon.

4.3.11.1.9.3. Post-Lead Turn Transition to Two-Circle Pursuit. In order to gain the initial advantage in the single-circle contest, the fighter may deplete energy to a state lower than or equal to the bandit's. As the fighter reverses, the fight now changes character, and the fighter sees a winning two-circle picture. At this point the fighter needs a positive ***rate*** Delta, instead of better radius, to win the two-circle pursuit. (See **Figure 4.57.,** Transition to Two-Circle.)

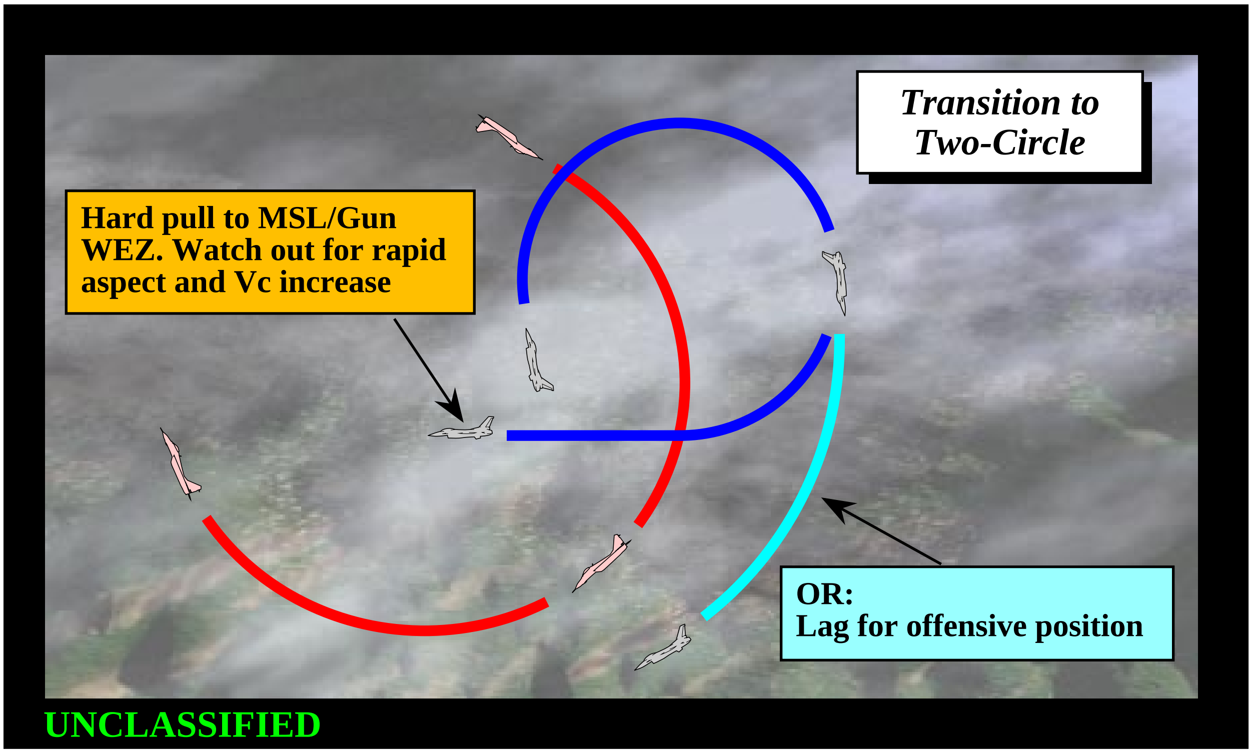
4.3.11.1.10. Losing Cues. Normally recognition of losing cues is not a problem in the Viper, but there are occasions where you may see a losing picture at the pass or during the turn. It is important to recognize this quickly and prepare to change the fight at the next pass.

Figure 4.56. Lead Turning Against a Radius Limited Bandit.



4.3.11.1.10.1. Single-Circle Losing Cues. Losing the first turn of a single-circle fight is usually caused by arriving at the merge with too much energy and/or not reducing energy quick enough when the fight becomes single-circle. (See **Figure 4.58.**, Single Circle Losing Cues.) The solution is to reduce power and pull Lv on while assessing the bandit's intentions. The loss of a one-circle contest will first be apparent at the 90 degrees point: the bandit's nose now is inside your circle. You are viewing the bandit out your 3/9 line, as he is looking at you forward of his. The largest indicator of how much is lost is determined by the bandit's drift rate across the horizon (slowing) or how fast the bandit comes nose-on. As the turn continues, the bandit's nose will come around to point at your aircraft before you can point back.

Figure 4.57. Transition to Two-Circle.



4.3.11.1.10.1.1. Lift limit and airspeed define the fighter and the bandit's Tc. The bandit's lift limit is similar to the fighter's (most fourth-generation types are). The bandit's smaller radius is due to slower airspeed. (See **Figure 4.59.**, Bandit Options.) So rate will probably be in your favor at the pass, so transition to a two-circle fight.

4.3.11.1.10.1.2. Do not continue to pull and arrive with 180-degree HCA, stay slightly out front to influence the bandit to reverse the turn into two-circle pursuit. Your energy advantage will then be optimized for the for the fight type (two-circle).

4.3.11.1.10.1.3. Easing out front will open you up to a fleeting gunshot and the possible permanent defender role. So minimize the amount while still "tempting" the bandit.

4.3.11.1.10.1.4. Turn in the same direction as before the pass—it will be the bandit's choice to reverse or not.

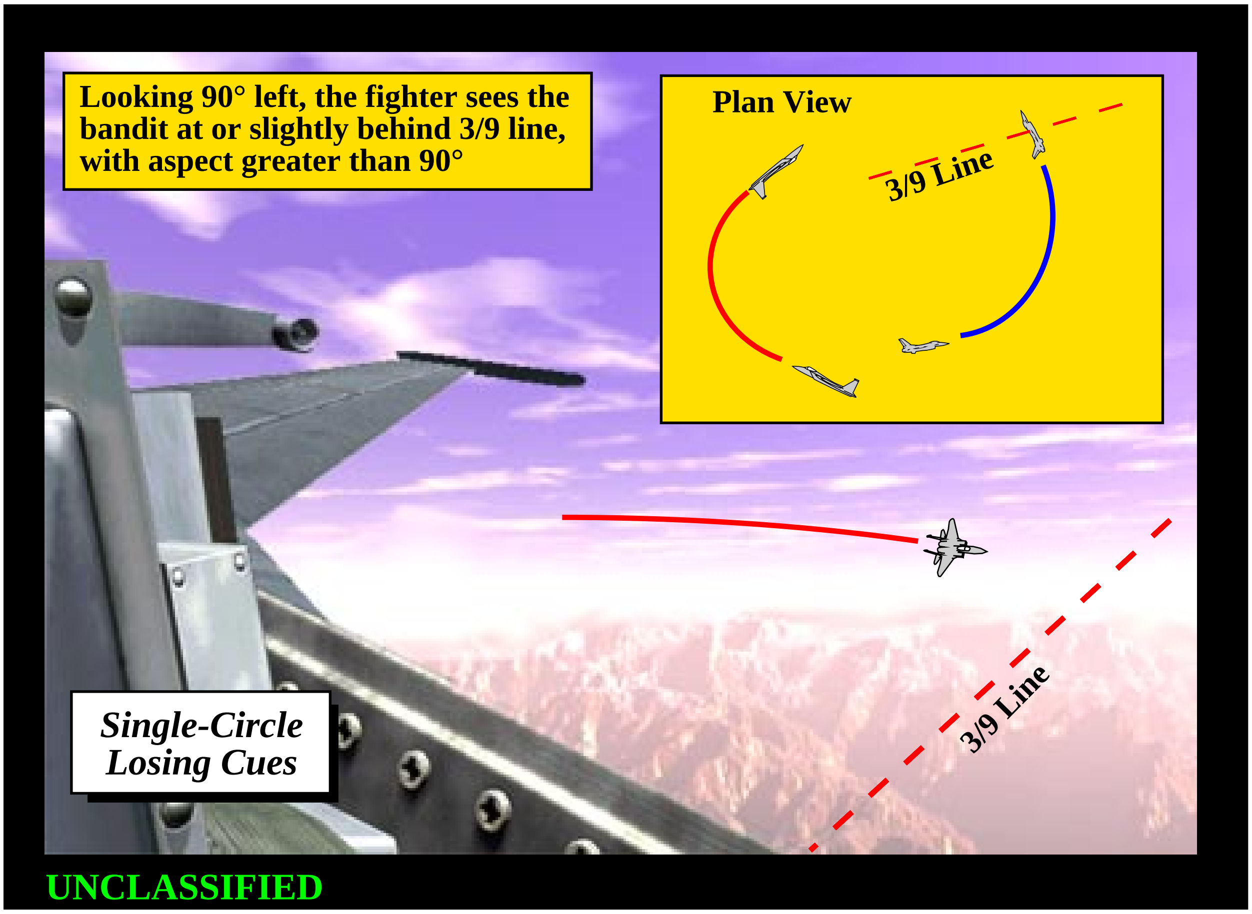
4.3.11.1.10.1.5. If the bandit goes the same direction as before the pass, any advantage gained will be lost.

4.3.11.1.10.1.6. If the bandit reverses into your higher energy two-circle plan, the bandit will probably get stuck in lag.

4.3.11.1.10.1.7. ***The Bottom Line*** : If you are losing the radius fight, switch to rate.

4.3.11.1.10.2. Two-Circle Losing Cues. Losing a two-circle fight may be hard to see until approaching the pass. You can project the loss by looking at your airspeed indicator. If it shows you well down the lift limit line, you will probably be at a disadvantage unless the bandit is also slow. Across the circle, the bandit will be slightly advantaged in HCA, and as the turn progresses, the bandit's nose will come to point at you before you can point back. Horizon drift and canopy movement are both dynamic and of little assessment value prior to the pass.

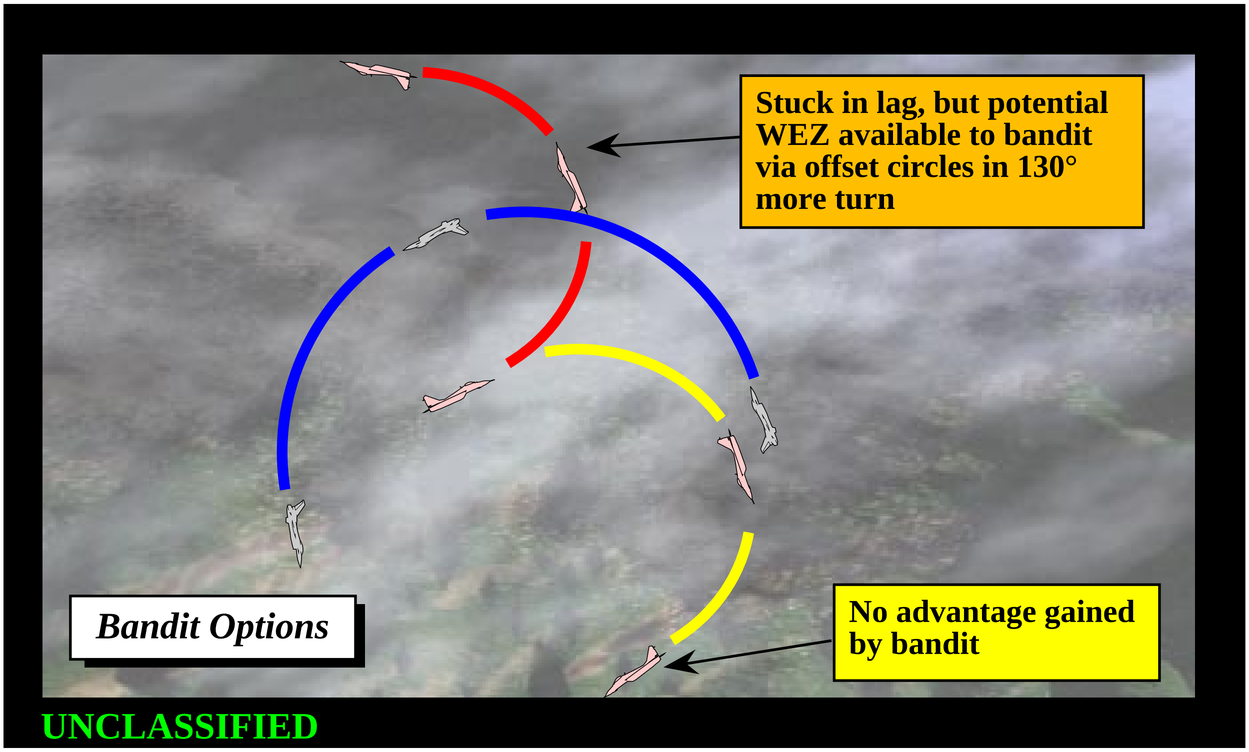
Figure 4.58. Single-Circle Losing Cues.



4.3.11.1.10.2.1. What to do if Losing. If the losing picture occurs, you may be losing the rate war. The only other choice is a radius fight. The adversary may have used up all his energy on this turn. Pull hard to prevent the adversary from lead turning you (Lv low will help). If at the second pass you are still losing, then it is time to switch to the radius fight (single-circle). (See **Figure 4.60.**, Losing the Two-Circle Fight.) Approach this pass as close to the bandit as possible. Any horizontal distance, as you reverse your turn direction away from the bandit at the pass is instant handicap. Spend the required energy to minimize it. The initial turn after the pass is not up, as in a rolling reversal, but Lv on in the same POM. In converting to single-circle, you force the bandit to slow down to stay aft of your 3/9 and bring the energy level down to yours.

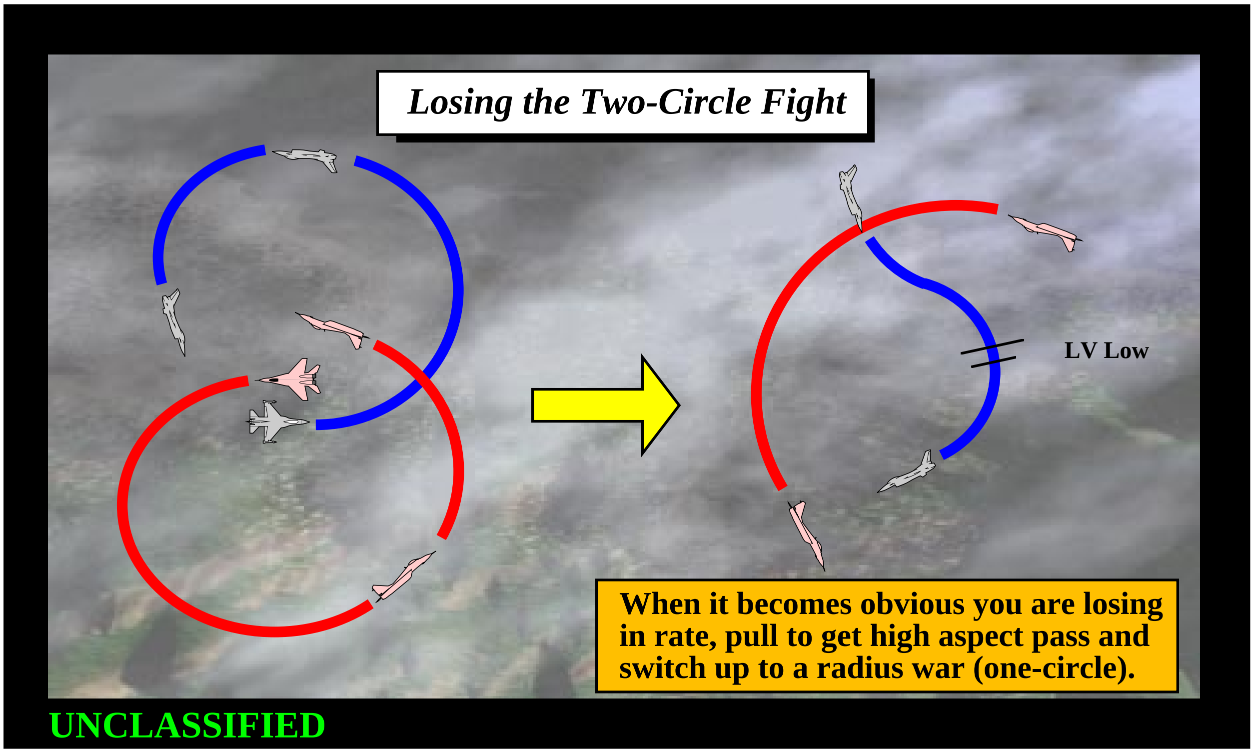
Both the fighter and the bandit are now "equal" and the win will go to the most efficient airframe and engine combination (assuming no cockpit buffoonery).

Figure 4.59. Bandit Options.



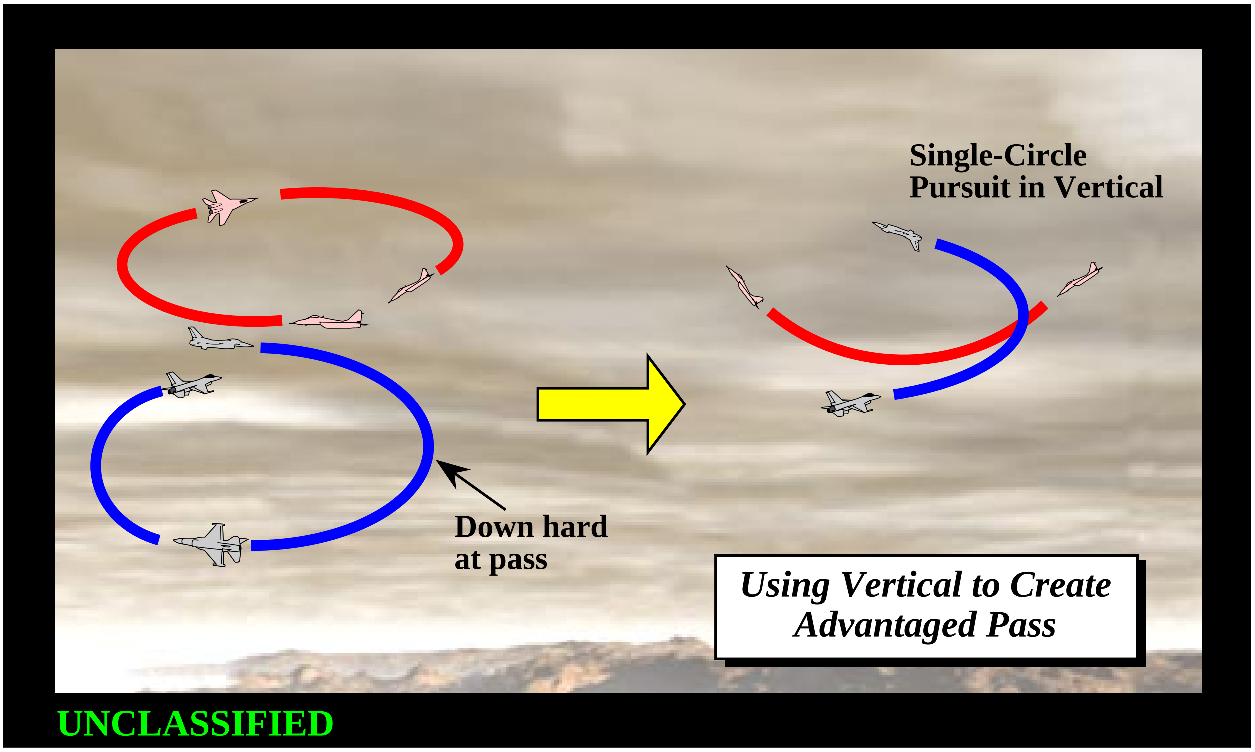
4.3.11.1.10.2.2. Losing the Fight in Altitude. If keeping up with the bandit's turn performance forces you to descend to pay off the P_s required, you are losing the fight in altitude. Recognition—you are at maximum G to keep up with the angles, and the bandit is against a blue background. Losing in a two-circle fight this way is the same as losing it horizontally. Continue to use altitude to gain parity at the pass and get close for the one-circle fight you want. The key to damage control is to switch to a radius fight. If you are losing horizontally, go down to match the bandit's angles while ensuring you will have the nose authority to point at the bandit at the pass.

Figure 4.60. Losing the Two-Circle Fight.



4.3.11.1.10.3. Creating the Advantaged Pass. Go down hard in either one- or two-circle fights and set up a low-to-high pass. At the pass convert to single-circle pursuit initiating a lift limit, Lv on pull toward the bandit with vertical G helping while the bandit is fighting God's G in a nose-low recovery. The resulting advantage for the fighter depends heavily on the vertical merge angle. (See **Figure 4.61.**, Using Vertical to Create Advantaged Pass.) If the nose position at the pass is less than 60 Degrees, optimize the result:

Figure 4.61. Using Vertical to Create Advantaged Pass.



4.3.11.1.10.3.1. Do not turn prior to the pass (unless it is to reduce spacing), because you seek single-circle pursuit. The bandit must select the turn direction for the nose-low recovery and commit first. The fighter will not have energy to change directions once committed.

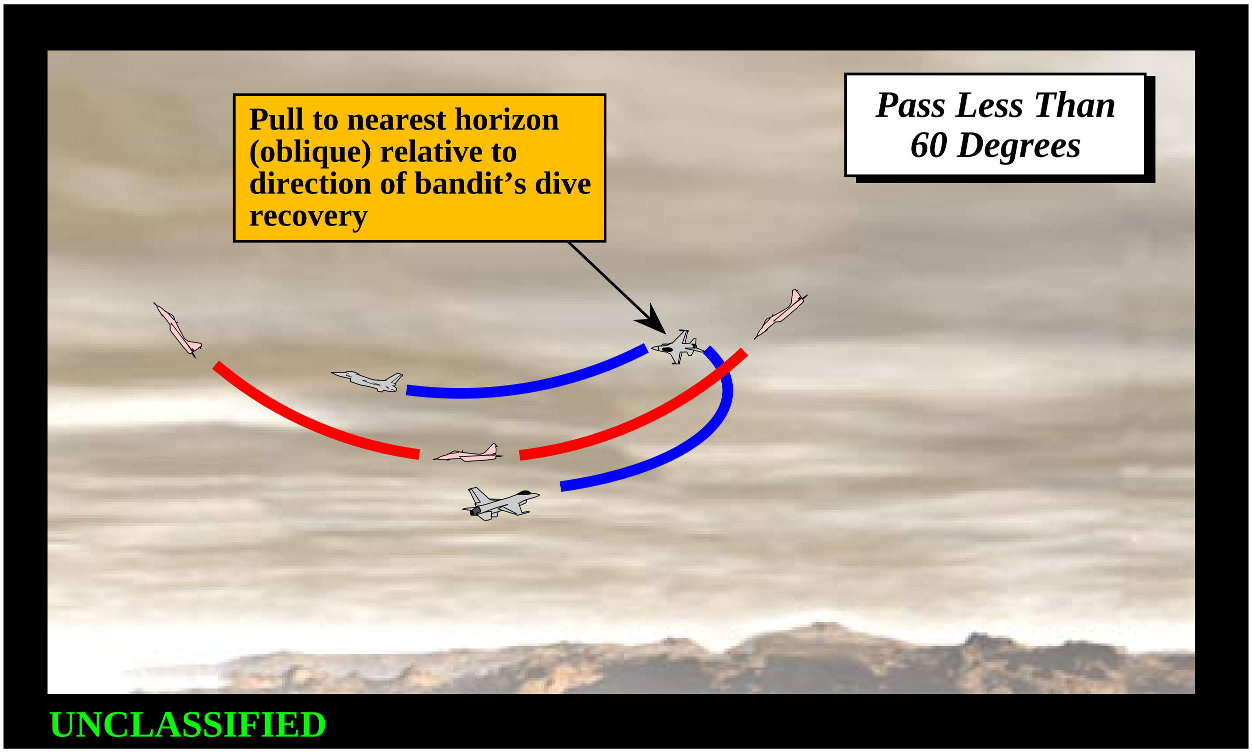
4.3.11.1.10.3.2. A common error is to follow the normal lead turn LOS cue and turn two-circle. To fight this tendency, the fighter should approach on the belly side of the bandit at the pass. This influences the bandit to turn down and accentuate the problem.

4.3.11.1.10.3.3. For a pure vertical pass, this is pretty straight forward, but as the elevation angle decreases, the fighter's pursuit course needs to go to the nearest horizon off the 3/9 line of the bandit.

4.3.11.1.10.3.3.1. If the fighter and bandit both go to the nearest horizon, it is two-circle pursuit. If the fighter goes pure single-circle over the top, the thrust vector will compete against gravity and delay the pursuit, giving away any advantage.

4.3.11.1.10.3.3.2. The bandit's best move is to simply pull to the nearest horizon, which forces the fighter to turn initially toward that horizon. Any other course by the bandit sweetens the pursuit for the fighter. (See **Figure 4.62.**, Pass Less than 60 Degrees.)

Figure 4.62. Pass Less than 60 Degrees.



4.3.11.2. Building a Game Plan. Now that high-aspect concepts are understood, it is time to apply them to develop game plans versus four common types of bandits:

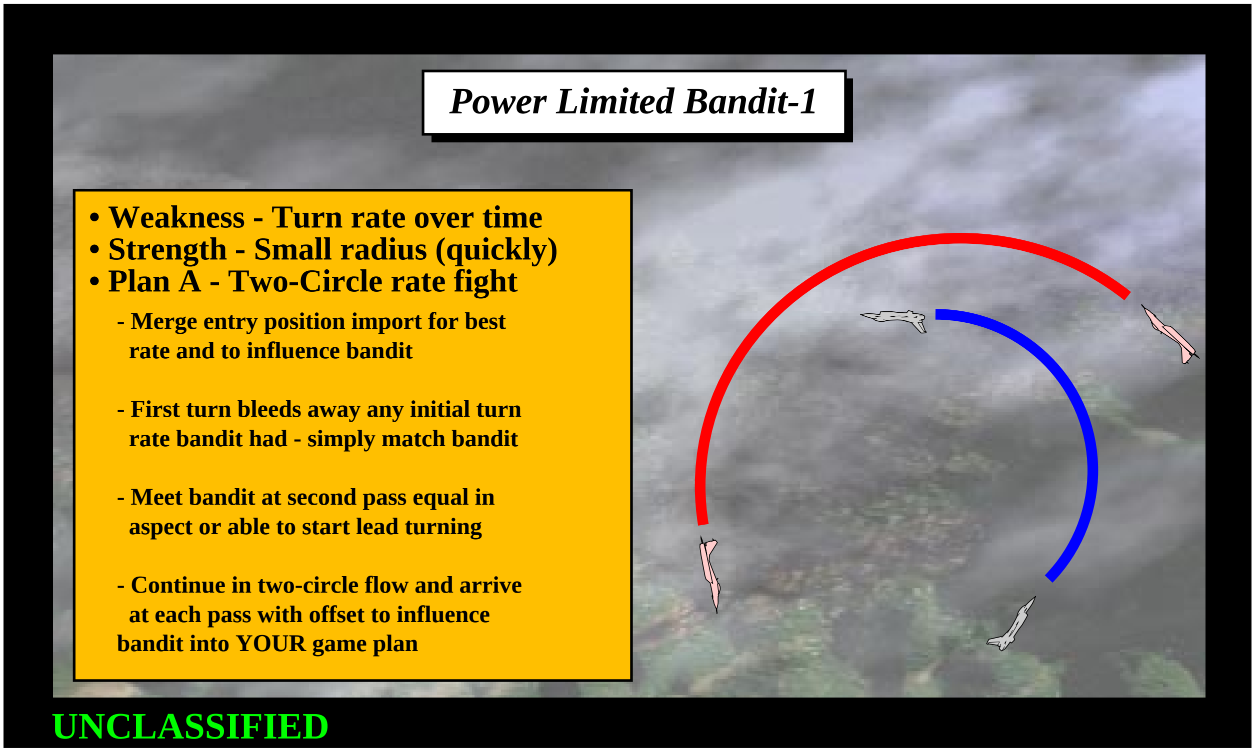
- Power limited.
- Turn limited.
- Energy deficient starts.
- Equal bandits.

NOTE: Fights are never truly neutral, and there will usually be some airframe weakness to exploit. Remember, the good bandit will predict your intentions and not let you get away with your desired plan, so have a backup. These discussions are maneuver oriented and allow for ordnance types common to the airframe. This is BFM, not "advanced, global, single air combat tactics for all occasions." There is never adequate space to lawyer every possible combination.

4.3.11.2.1. Power-Limited Bandit. The power-limited bandit operates at a lower P_s for a given energy state than the F-16. The airframe may be able to generate an equal or higher turn rate for a short time at high airspeed. Speed decay will be faster, and a turn rate deficit will result. The bandit's strength in the first turn of the fight is a smaller turn radius due to the slower speed. To stay even in a single-circle fight you will have to slow down. Try to influence a two-circle fight. Plan A starts slightly high with horizontal offset at the merge to allow a Lv downward turn to establish the best rate. This first turn will be a status quo (just matching the bandit) turn to arrive at the next pass with the same entry picture as the first pass. The fighter uses roll control to hold the bandit near the horizon. If the bandit uses the vertical, stay equal by adjusting your Lv with roll.

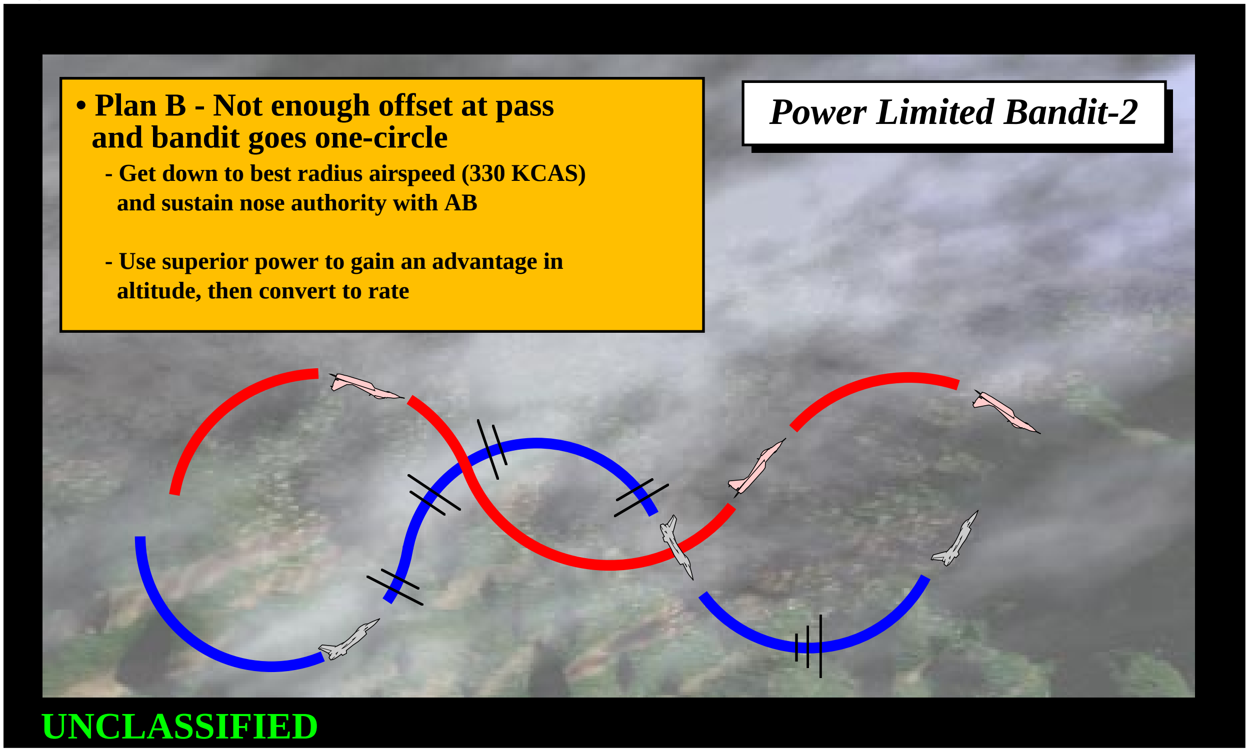
4.3.11.2.1.1. Two-Circle. The bandit is turn rate deficit, and you want to keep going two-circle to preserve your rate advantage. At each subsequent pass, you will be able to point first, but before getting nose on, stop the turn and hold the bandit about a clock position away from the nose until LOS rate accelerates on the horizon. Then lead turn, Lv low. This sets up the horizontal distance that makes the bandit keep the two-circle turn going. If the bandit tries to convert to single-circle at this point, the bandit will commit suicide by flying out in front of you in your gun envelope. Each subsequent pass is the same, use the altitude above the bandit to reduce the negative P_s payout during the lead turn. (See **Figure 4.63.**, Power Limited Bandit-1.)

Figure 4.63. Power Limited Bandit-1.



4.3.11.2.1.2. Forced One-Circle. Plan B happens anytime the fighter is unable to influence the turn direction at the pass. Give the bandit the opportunity to fight single-circle, and a smart one will. The bandit wants out of the losing rate war, and into something more favorable. When this happens, look at the airspeed indicator to determine the power requirement. A single-circle fight is a radius war. If you are 330 KCAS or below, your radius will be relatively unaffected in the next turn regardless of power—keep it in AB for best rate. If it is above that, you will want to reduce power to minimize the radius as quickly as possible. As soon as you get below 330 KCAS, reselect AB. The key to winning the single-circle fight against a power-limited bandit will be gaining the offensive position or recognizing that you are in a scissors and make the correct move for an energy advantaged fighter (stack). (See **Figure 4.64.**, Power Limited Bandit-2.)

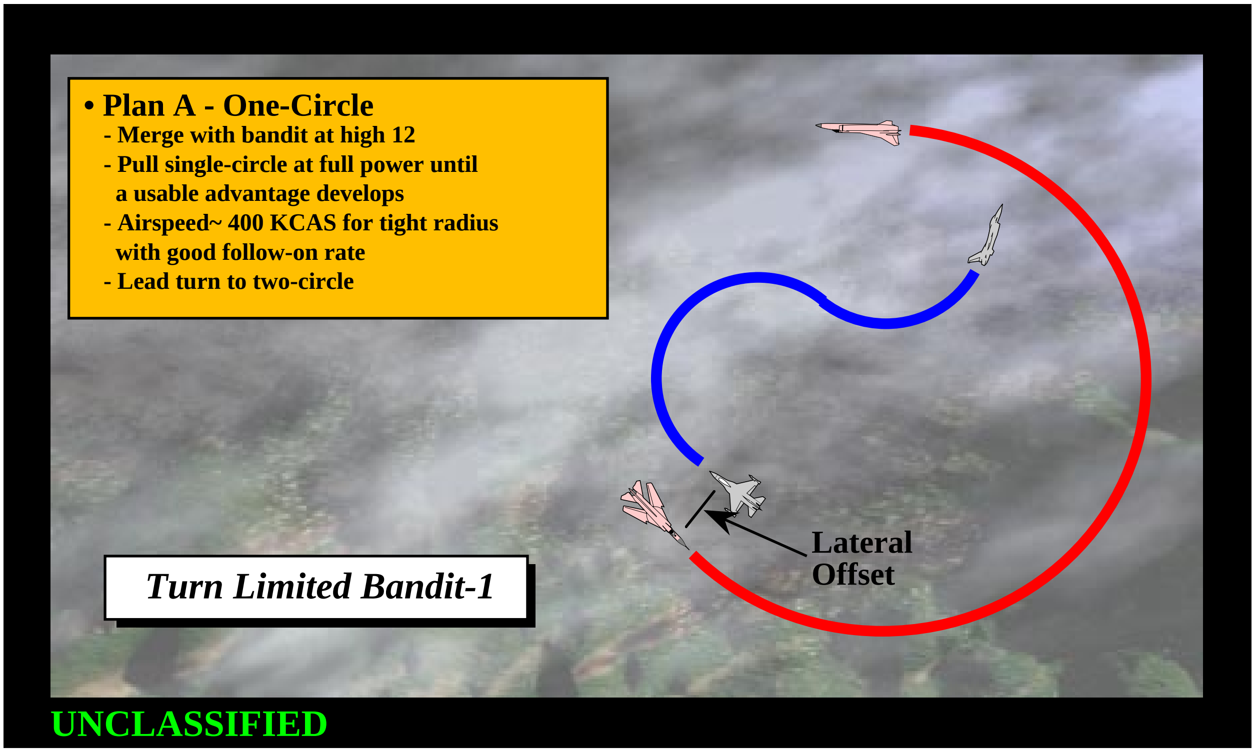
Figure 4.64. Power Limited Bandit-2.



4.3.11.2.2. Turn Limited Bandit. Turn limited bandits are usually easy to deal with since they are both radius and rate limited. A turn limited bandit (not CAT III bandit) also has some P_S problems that reduce the rate even farther as the turn progresses. Turn limitations are generally a result of carrying external stores or a poor airframe capability in G or lift. At any rate, this fight is usually quickly settled by a single-circle plan.

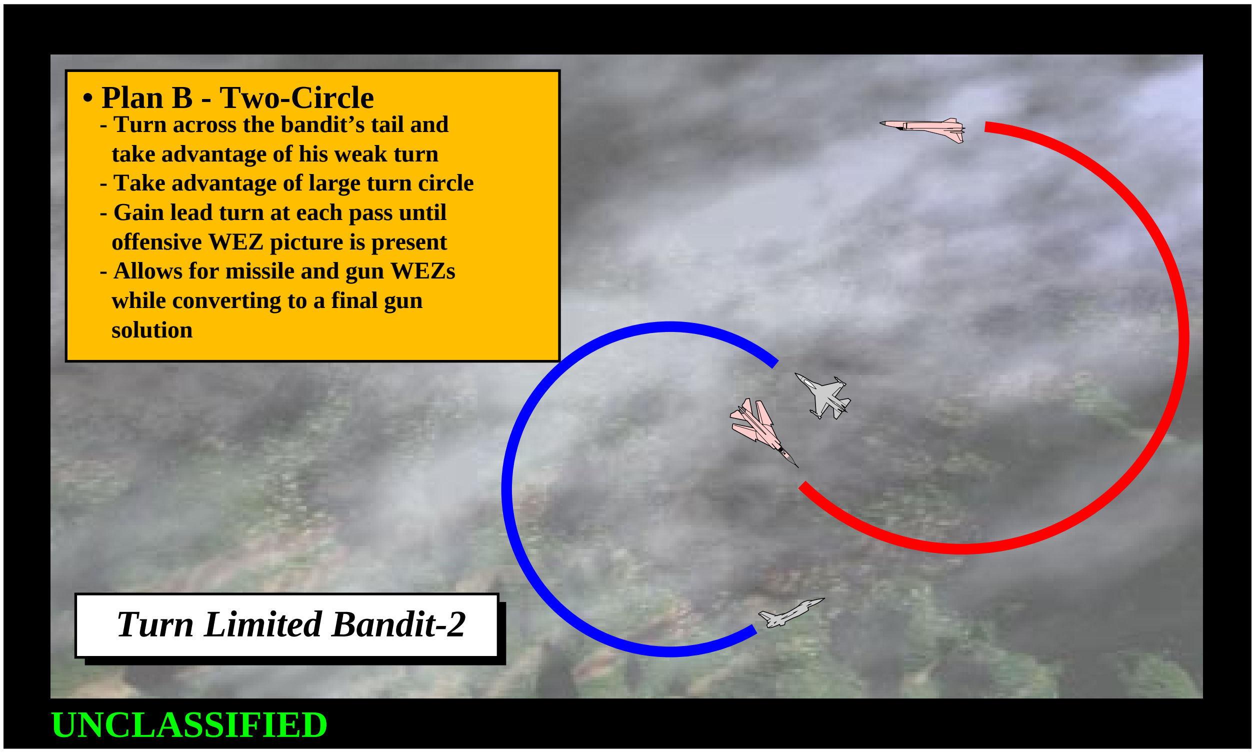
4.3.11.2.2.1. Single-Circle. The fighter would like to merge with the bandit dead center at high 12 o'clock at the pass. This cuts out all horizontal handicap and provides the best visibility through the merge. Establish single-circle pursuit with full power after the bandit starts turning. The single-circle advantaged cues develop quickly while holding the bandit near the horizon. The fighter's pull should ensure a usable advantage at the second pass and not bleed P_S at the maximum rate. This (inside the turn advantage) will set up a two-circle lead turn on the bandit. The pursuit will require airspeed for best rate to square the corner and establish control. The fighter can generally use AB throughout to preserve follow-on energy since the turn-limited bandit cannot compete in the radius war. (See **Figure 4.65.**, Turn Limited Bandit-1.)

Figure 4.65. Turn Limited Bandit-1.



4.3.11.2.2.2. Two-Circle. Plan B for the turn-limited adversary is a two-circle fight. This option will only be due to a bandit head fake or from the fighter entering with initial turn with horizontal offset. The fighter will notice the advantage cues developing and the fight opening up more than normal due to the bandit's large Tc. Complete the turn with an optimum pull preserving airspeed to close the circles up and collapse the turn centers. This is done in full AB, nose low and only enough G to ensure an angular advantage at the next pass. A common error is to pull at the aft limit to generate a big advantage picture and then have no energy left to pursue it. At the pass, the fighter must keep pulling only to gain advantage—not at the aft limit. This preserves turn rate for the next pass, which will be a well-advantaged, two-circle lead turn, heading for the control position. (See **Figure 4.66.**, Turn Limited Bandit-2.)

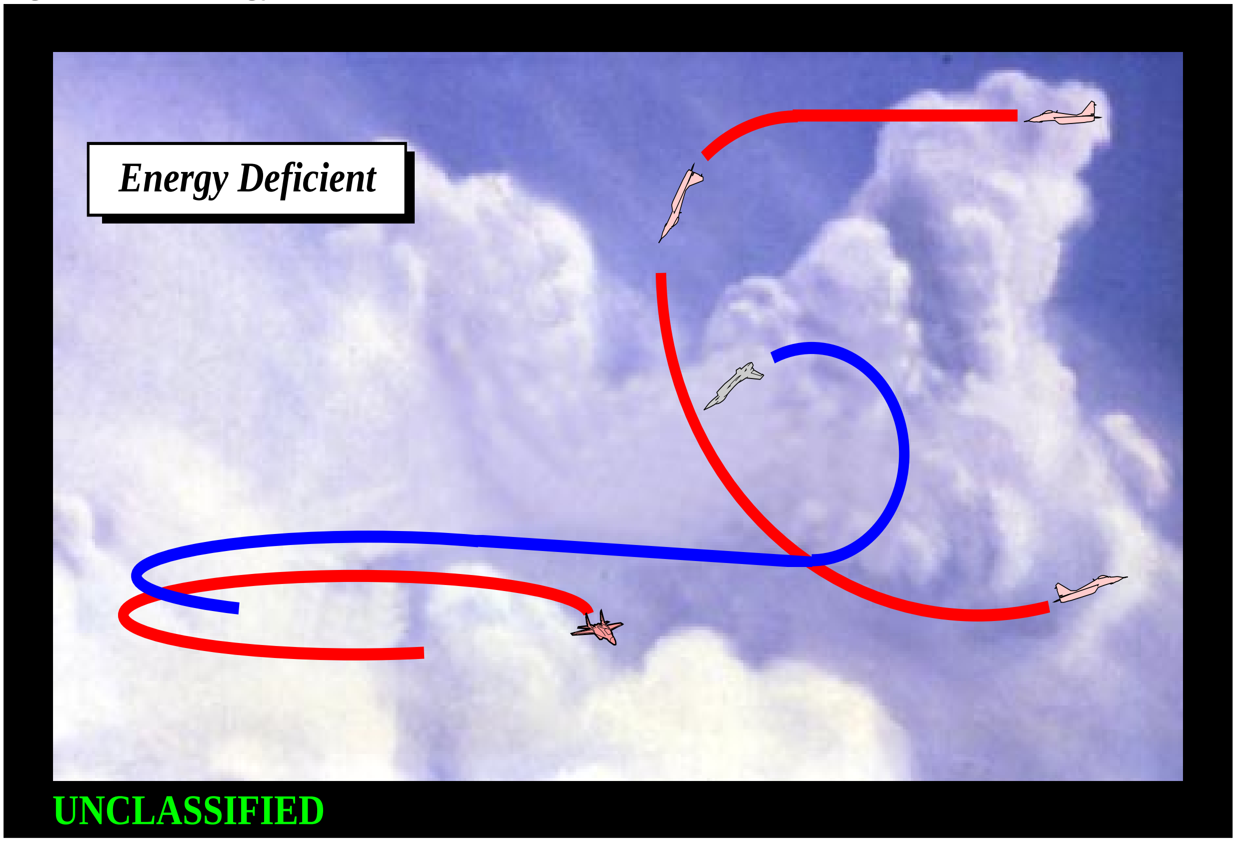
Figure 4.66. Turn Limited Bandit-2.



4.3.11.2.3. Energy Deficient Start. Some fights start with less than optimum energy. This may be due to late jettison decisions, threat reactions, or intercept errors. Some examples are: dumping out of one fight into another, defending your way to the merge, or climbing to the merge in idle. There are no fighters that enjoy a clear advantage over the F-16. The energy problem is temporary, and with the proper game plan, you can drive the bandit down to an equal energy state. The bandit's advantage is then gone, and the fight is on more equal terms. (See **Figure 4.67.**, Energy Deficient.)

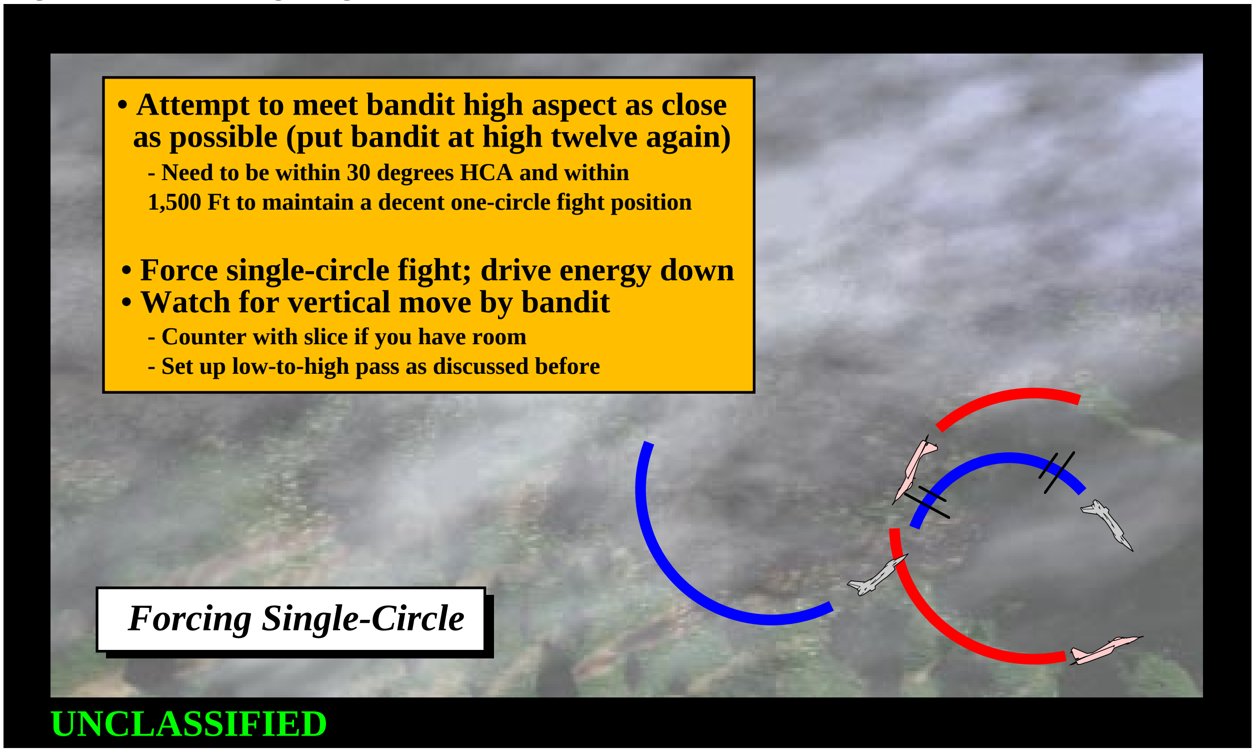
4.3.11.2.3.1. Energy Deficient Basics. A quick recap of energy principles is in order. Low energy means low turn rate. It also means a small turn radius. If the bandit has to deal with a small radius in the first turn, he will have to reduce his energy level to avoid being spit out front. This is the foundation of plan A.

Figure 4.67. Energy Deficient.



4.3.11.2.3.2. Forcing the One-Circle Fight. Plan A starts with a pass directly under the bandit to afford the best opportunity to get the single-circle fight started. (See **Figure 4.68.**, Forcing Single-Circle.) This decision reduces the bandit's WEZ at the next merge to a minimum. The fighter's small radius forces the bandit to reduce power (or go up) to cope with the next pass. If the bandit elects to stay with the fighter in the horizontal, the energy state will drop to the level of the fighter and the fight will equalize (which is better). If the bandit chooses to convert the excess kinetic energy into potential by going up, the fighter must recognize the opportunity to convert this to a low-to-high turn at the next pass as discussed in **paragraph 4.3.11.1.9.3**, Post-Lead Turn Transition to Two-Circle Pursuit. The key execution point is to ease off the turn enough to be able to point at the bandit at the pass and force his nose down to exploit the single-circle turn. The vertical merge angle will be the deciding factor of how much you can get after the pass. If you have the luxury, go deep and pull up steep. Make the pass as close to vertical as you can to gain the maximum advantage. In a single-circle entry to this pass, the amount of vertical you can generate will be small, but the key to the pass is angle, not distance. The bandit has objectives also and will probably see the energy situation from the vantage point of the best game plan too. If the pass occurs with greater than 1,500 feet offset or more than 30 degrees AA, the single-circle plan may not be available—you may have to fight the two-circle fight—plan B.

Figure 4.68. Forcing Single-Circle.

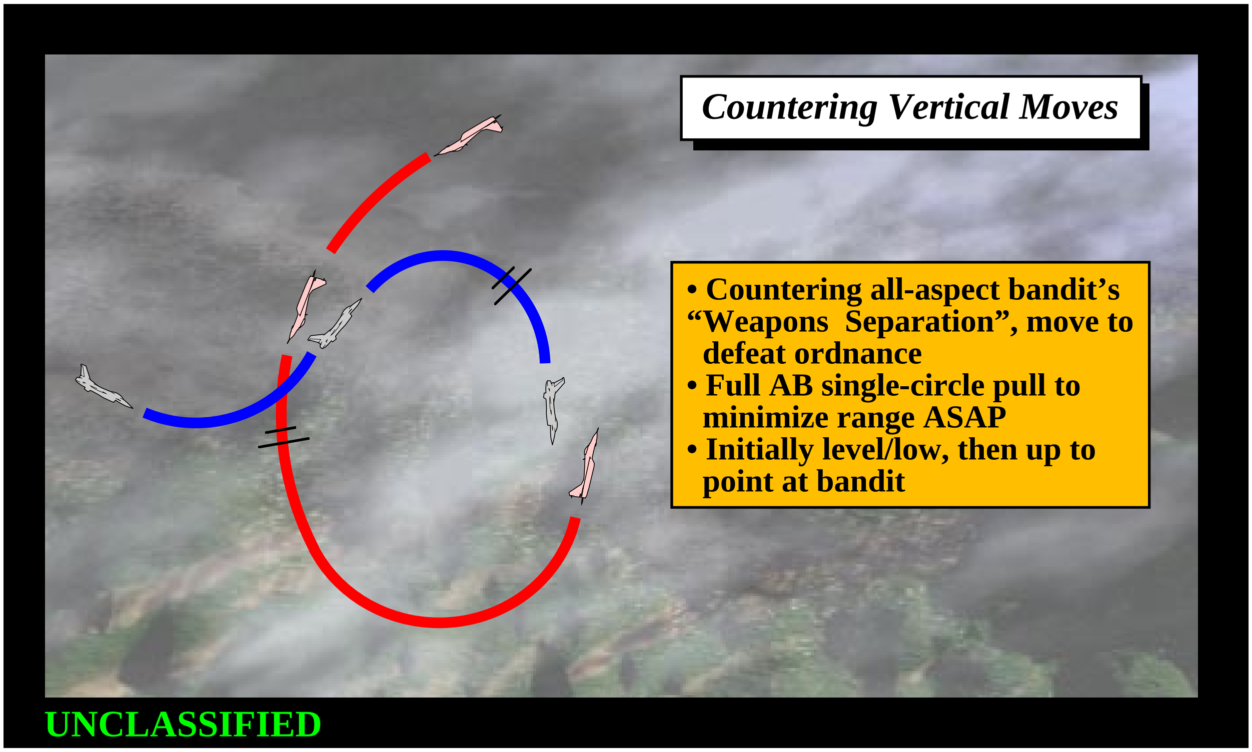


4.3.11.2.3.3. Forced Two-Circle. The key energy concept here is the realization that this fight cannot be won by you, and only plan A will save you. The bandit that carries all-aspect ordnance (both radar and heat) has some institutional baggage that results from their list of "golden truths." The bandit may go up at the pass to seek the best turn rate to get the nose back on you for weapon employment. If low energy were not the issue here, the best move would be to go up with the bandit. The problem is that the bandit vertical capability can create enough range to gain a WEZ if you do not maneuver to keep the range tight. In most cases, the bandit will have to come around the corner nearly all the way before a shot opportunity exists. The fighter can deny a shot generally with a tight, near-the-limit turn and efficient vertical use to force the bandit back in to the execution at the pass.

4.3.11.2.3.3.1. Start with the fighter rolling the Lv down approximately 135 degrees to gain a turn advantage before the bandit makes it over the top. The pull around the corner must be as hard as possible while preserving "over the top" airspeed for the next pass. As the bandit pulls to pure pursuit, the fighter will be coming up toward him in minimum time and close the range. Set it up so single-circle after the pass is available. The prosecution after the pass is the low-to-high turn discussed in **paragraph 4.3.11.1.9.3**, Post-Lead Turn Transition to Two-Circle Pursuit.

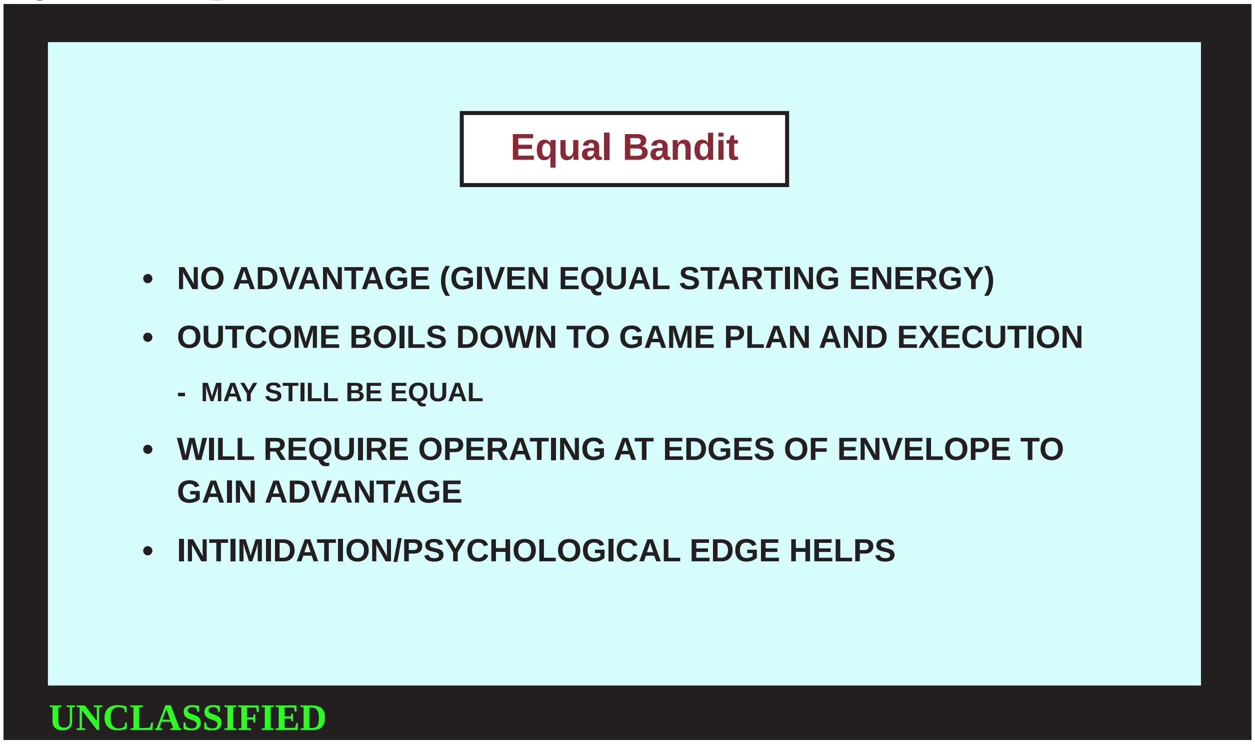
4.3.11.2.3.3.2. In two-circle fights, the range developed between adversaries is greater than the single-circle case. This makes the set up of the low-to-high scenario easier, but it also opens up the WEZ for high-aspect ordnance. Do not get greedy with the vertical down move. Get around as quick as you can while preserving the speed requirement. Opening up the turn at the bottom will definitely create ordnance possibilities for the bandit. Once advantage is established, the bandit will be equal energy-wise, and the fight will be in your favor. (See **Figure 4.69.**, Countering Vertical Moves.)

Figure 4.69. Countering Vertical Moves.



4.3.11.2.4. The Equal Bandit. Fighting a bandit equal in capability has a predictable result when both adversaries approach with equal knowledge—a low speed, close range stalemate at the floor. The problem here is that each move initiated by one can be countered by the other. These fights are the primary reason that there needs to be a "designated training aid" and "fighter" in all high-aspect BFM training. The problem is there are an ever-growing number of airframes that approach maneuvering parity with the F-16. Now, the spread between capability is narrower and must be addressed. The problems the fighter faces at the merge with an equal bandit are frustrating. The turn rate and radius are the same. (See **Figure 4.70.**, Equal Bandit.) When the bandit approaches a performance limit, the fighter does too (assuming equal energy levels). There is no clear advantage available through the throttle or stick. The fight outcome will depend on the two variables left—the game plan and the pilot flying it. These fights typically rely on the extreme edges of the flight envelope and the exploitation of the gravity vector in the vertical. Adversary mistakes are generally the deciding factor. Psychology and intimidation are important tools in this fight. The best method to win is to master all the fundamentals of this section coupled with the ability to exploit the full envelope of the aircraft both legally and knowledgeably. It is a highly variable exercise of your understanding of high aspect BFM because of the spectrum of adversary knowledge you may face.

Figure 4.70. Equal Bandit.



4.4. Air Combat Maneuvers. Air combat maneuvers (ACM) normally involves coordinated maneuvering between two fighters employing BFM to kill, defend or separate from one or more bandits in a visual merge. The engaged phase can be the outcome of the intercept phase or an undetected bandit entry, and is the highest risk phase of an A/A engagement. Distinct roles, or an "ACM Contract," must be briefed and established between the two fighters prior to any flight with the potential for air combat basic training (ACBT) in order to ensure effective ACM. This contract defines "engaged," "supporting," and "defensive" roles. Disciplined execution of these roles is critical for survivability and lethality. Any break down in the established "ACM Contract" can lead to undesirable and disastrous outcomes, (i.e., midair)! ACM objectives are:

- Develop proficiency in two-ship coordinated maneuvering.
- Teach specific engaged and supporting fighter roles in a visual fight.
- Develop enhanced SA.

4.4.1. Communications. Clear, concise, and correct communications are vital for effective element employment. Each pilot must firmly understand MPM, Brevity Terms, and unit standard terminology, to be able to use the correct terms at the correct moment in a fight. If the situation cannot be addressed using MPM Brevity Terms or unit standard phrasing, use clear text to accurately describe your intentions or maneuvers. Only daily practice and constant critique gain proficiency in communication. The time to start improving your communication is not after the first "BREAK RIGHT" call. The planned cadence, communication procedures, and brevity terms used during the flight should be reviewed in the flight briefing to enhance their effectiveness. Shortening communications can be a bad habit that fighter pilots need to avoid. Nonstandard radio terminology, combined with excessive verbiage can cause confusion, misinterpretation, and override more critical information—***the result may be fatal***. Use full call signs when beginning radio transmissions to gain the attention of other flight members and allowing uninvolved flights to "tune out" your transmission. All missions (not just A/A) should focus on communications discipline!

4.4.1.1. ACM Communication. As part of a fighting team, situations develop quickly as you maneuver. As the bandit maneuvers, communicate what you see in the most efficient way. MPM, standard communications terms specific to ACM:

- "DEFENSIVE": Aircraft is in a defensive position and maneuvering with reference to the stated condition.
- "ENGAGED": Maneuvering with the intent to kill. Implies visual/radar acquisition of target. "ENGAGED OFFENSIVE" or "ENGAGED NEUTRAL," communication time permitting and SA enhancing.
- "PRESS": Directive to continue attack; mutual support will be maintained. Supportive role will be assumed. Role swap occurs.
- "CLEARED": Requested action is authorized (engaged or support roles are not changed or assumed). If in response to an "engaged" request, the original supporting fighter retains deconfliction responsibility.
- "NEGATIVE": Requested action is denied. Maintain previous role.

4.4.1.1.1. Flight Lead Communication. Flight leads retain the communications authority to determine engaged and supporting roles. An "Engaged" call by the flight lead is directive in nature: it ***automatically*** drives a role exchange. The wingman can only reply with "Cleared" or "Press." The flight lead is the assumed "Engaged" fighter, prior to the engagement. The wingman should strive to fulfill the supporting role.

4.4.1.1.2. Wingman Communication. Wingman fulfill the supporting role prior to role changes as directed by the flight lead. Wingman communication, by definition, is ***not*** directive, unless directing the flight to ensure survival. The only engaged call that automatically directs a role change by either fighter is "DEFENSIVE." If the flight lead, as the engaged fighter, needs the wingman to assumed the "ENGAGED" role, it will be requested (possibly by an "ENGAGED, NEUTRAL" call). The wingman will then make an "ENGAGED" call, and the flight lead can reply "CLEARED," "NEGATIVE," or "PRESS." (See **paragraph 4.4.11**, Entries.)

4.4.1.2. Directive Transmissions. A directive call is required when a threat warrants an immediate reaction for survival. Directive radio transmissions must be prefaced by the call sign of the aircraft or flight being addressed (i.e., "VIPER ONE, BREAK RIGHT!"). After making the directive transmission "VIPER ONE, BREAK RIGHT," pause, look, and see if lead is doing what was directed. If not, re-transmit the directive call. The priorities need to be placed on the execution of the directed action. All other mission tasks are secondary until the threat has been negated or defeated. The supporting fighter may be required to make a series of directive calls due to limited time. "VIPER ONE, BREAK RIGHT," "VIPER ONE, JINK NOW," "VIPER ONE EXTEND," if the supporting fighter has the tally and there is no time to describe the bandit's position without jeopardizing the safety of Viper One.

4.4.1.3. Descriptive Transmission. Descriptive transmissions are normally prefaced by the call sign of the aircraft doing the talking, (i.e., "VIPER ONE, TALLY BANDIT, LEFT 10, 5 MILES, LEVEL.") When a directive action is required, the descriptive communication must come after the directive transmission and action is taken. Then, describe why you made the directive call. The bandit descriptive call is important for it will allow Viper One, in this example, to acquire the tally and perform the proper BFM to defend himself. The bandit call has been standardized into the format shown in **Table 4.4.**, Standardized Transmission Format, which should always be used.

Table 4.4. Standardized Transmission Format.

Standardized Transmission Format.
· Call sign
· Type aircraft, or threat (bandit /bogey)
· Left or right (side of aircraft)
· Clock position
· Range
· High/low/level
· Amplifying remarks
EXAMPLE: "VIPER TWO, BANDIT, RIGHT 2, 3 MILES, HIGH."
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4.4.1.3.1. A modification of the format shown in **Table 4.4.**, Standardized Transmission Format, is used to follow up a directive call if your element mate is under attack. Here is an example: "VIPER ONE, BREAK, RIGHT," pause (as the directive action is being taken), then continue with the descriptive communication: "BANDIT, RIGHT 5, 9,000 FEET, LEVEL." In this case, the position of the bandit is described with reference to the aircraft under attack. Continue descriptive communication until the defensive fighter is "Tally-ho."

4.4.1.3.2. Sometimes subsequent descriptive calls may include the word "CONTINUE." This informs all flight members that the only reaction required is the maneuver that is being performed. For example, Viper One calls, "VIPER FLIGHT, HOOK RIGHT," "VIPER ONE, BANDIT, RIGHT 4, 5 MILES, SLIGHTLY HIGH, CONTINUE RIGHT."

4.4.2. Formation Integrity. Formation integrity is an integral part of all element maneuvering. In the ACM environment, formation integrity allows both the engaged and supporting fighters to maneuver synergistically to defeat the bandit's attack. Mutual support and formation integrity are critical to success. The engaged or defensive fighter must do the best 1v1 BFM to kill or survive the bandit's attack, while the supporting fighter maneuvers to kill the bandit, or support the engaged fighter, based on the criteria defined by the flight lead.

4.4.3. Flight Discipline. Flight discipline is an important factor effecting the success of fighter employment. This requires adherence to clearly defined responsibilities and decisions based on the flight lead's overall game plan and philosophy of employment. Executing your duties based on the flight lead's plan (i.e., set of assumptions and guidelines) fulfills the flight contract. The flight lead can assess the success or failure of the plan and make changes. Obviously, no pilot should do anything to place all flight members in a defensive situation. However, changing or ignoring the flight lead's directions based on personnel preference is unacceptable! When a flight lead makes a directive call, the wingman must respond with the directed action to the best of his ability. If the wingman uses a "directive" term/word, it is a request and the flight lead reserves the right to approve/deny the wingman's requested action. Example: "VIPER 2, ENGAGED, HIGH- NORTH" "VIPER 2, NEGATIVE"

4.4.4. Weapons Employment. Knowledge of weapon system capabilities and limitations will allow the pilot to make accurate decisions concerning weapons employment. Apply BFM skills to maneuver to a WEZ, then effectively employ weapons to kill. The status of your element mate and yourself will effect your decision to maneuver immediately to a WEZ, defend, or reposition.

4.4.5. Engaged and Supporting Fighter Contract. Most units have "standards" that provide essential, clear, and unique procedures to ensure success in training and combat sorties, minimize briefing time, clarify ambiguities, and establish a common point of reference. These "standards" need to be fully understood by every pilot in that unit. An effective "ACM Contract" assigns responsibilities between two aircraft that are essential to take full advantage of the element's capabilities during an A/A engagement. In the flight briefing it is the flight lead's responsibility to ensure complete understanding of the "ACM Contract." The division of responsibilities serves two basic purposes: killing the bandit and ensuring element survival. The ingredients required for successful execution of the "ACM Contract" is mutual understanding of the game plan and a correct balance of communication, mutual support, executions of responsibilities, and weapons employment. The heart of the "ACM Contract" is the establishment and adherence to ACM roles. There are three roles: engaged (offensive or neutral), defensive, and supporting. Flight members ***must*** fully understand their responsibilities.

4.4.5.1. Engaged Fighter Role. If no fighter is defensive, there can only be ONE actively engaged fighter at a time. If there is a defensive fighter, the engaged fighter must assume deconfliction responsibility. In a dynamic environment, such as A/A, the roles may change rapidly from one to the other several times. Engaged fighter responsibilities:

- Maneuver to kill the bandit in the minimum time. Fly your best BFM.
- Clear the supporting fighter to engage if in a better position to kill the bandit quickly.
- Keep the supporting fighter informed of intentions, status (i.e., transition from offensive to neutral), and future tactical plans.
- Deconflict the fight if the other fighter becomes "Defensive."

4.4.5.2. Defensive Fighter Role. The fighter (the bandit is engaging offensively) should be defensive—the primary concern is to survive—all other mission tasks are secondary. Responsibilities include:

- Do not hit bandit or rocks.
- Fly the best defensive BFM.

4.4.5.3. Supporting Fighter Role. The supporting fighter may have to perform two or more tasks/responsibilities at the same time. Time sharing between the tasks at hand is required to effectively support the engaged or defensive fighter. The time allowed to perform a given set of tasks will be scenario dependent. The two highest priority tasks of the supporting fighter are flight path deconfliction and not becoming defensive.

4.4.5.3.1. Primary responsibilities:

- Deconflict from element mate (maintain visual).
- Do not become defensive (gain/maintain tally).

4.4.5.3.2. Secondary responsibilities:

- Maneuver for a shot of opportunity. Employ ordnance consistent with the leads game plan, without compromising the engaged fighter's safety, clear avenue of fire (CAF), and frag deconfliction.
- Sanitize the area around the fight through visual and electronic means.
- Engage other bandits that have become threats to the element and keep the engaged fighter informed.
- Maintain overall SA to include area orientation, fuel, and exit avenues.
- Direct the egress.

4.4.5.4. Element Goals. The goal of the element is to achieve the quickest possible kill. As soon as the supporting fighter can ensure deconfliction and not go defensive, the fighter begins maneuvering for a shot on the bandit. This does not imply that a role change will be required. In most cases the supporting fighter should be able to employ ordnance without a role change. If the engaged fighter is offensive, a role change is usually not warranted, but the supporting fighter should employ ordnance IAW the briefed criteria for shots of opportunity. If the engaged fighter becomes neutral, the supporting fighter should maneuver to kill the bandit as quickly as possible. A role change is not necessarily required, but is an option (i.e., if only the gun is available). If a fighter goes defensive, the supporting fighter must maneuver immediately to kill the bandit. This may dictate entering a gun WEZ (control zone), while retaining flight path deconfliction. CAF requirements must be carefully weighed against element mate survival in a defensive situation. Squadron standards or the flight brief should address this issue.

4.4.6. The Flight Lead/Wingman Relationship. The previous discussion does not equate engaged and supporting roles with leader and wingman positions; this is intentional. Our tactics are designed to allow the best-positioned fighter to engage the bandit offensively. This should not imply break down within the basic flight lead/wingman responsibilities. The flight lead still has the ultimate responsibility for mission accomplishment and flight survival. The flight lead also makes the decisions about whether or not to engage, what tactics will be used, and who will do the engaging or separating. While the wingman is engaged, the flight lead supports him but retains the authority to direct the engagement, to terminate the engagement, and to assume the engaged role.

4.4.7. Engaged and Supporting Fighters Responsibilities. The engaged/supporting responsibilities work effectively in most 2v1 situations, however, when the contract breaks down, the flight may present a danger to itself. Confusion of roles is the most common problem. Two fighters, each thinking they are engaged, can easily end up occupying the same airspace. For this reason, flight and element leads will brief engaged and supporting responsibilities, maneuvering deconfliction, role changes, and desired engaged communications prior to any flight with the potential for ACBT maneuvering. Element or wingman deconfliction subsequent to a blind call or planned loss of sight tactic will be briefed for any planned intercept or ACBT flight where more than one element or more than one fighter may be maneuvering against the same bandit or bandits.

4.4.8. Shots of Opportunity. Supporting fighter shots of opportunity exist when the bandit is in a WEZ; CAF can be met; bandit's debris is not a factor to the engaged fighter; and the supporting fighter will ***not*** enter the engaged fighter control zone (the airspace between the engaged fighter's nose to the bandit). If adequate distance is not provided, the bandit's debris could endanger the engaged fighter. As a ROT for a missile shots of opportunity, the bandit's aspect to the supporting fighter should be approaching the beam. To employ the gun, the supporting fighter is going to have to perform a role exchange to be allowed into the engaged fighter's airspace. Under most circumstances the gun opportunity will be fleeting and should only be attempted if it is the only shot available. During shots of opportunity the supporting fighter is always responsible for deconflicting with the engaged fighter. Shots of opportunity support killing the bandit quickly, thus minimizing a turning engagement. Flight leads may impose additional restrictions for shots of opportunity. With a “Defensive” fighter, the first and fastest valid shot is appropriate. CAF may not be required.

4.4.9. Supporting Fighter Maneuvering. An engaged fighter flying his best BFM or a supporting fighter maneuvering for a shot of opportunity requires turning room to not only turn to point at the bandit, but also to have weapons separation for a WEZ. With the advent of the all-aspect adversary, achieving this turning room by extending outside the fight with the old “check and extend” plan may not be survivable. The bandit may only need to turn 90 degrees before threatening the supporting fighter, thus limiting the time available to extend away from the merge. In no case does the supporting fighter want to become defensive while maneuvering for the required turning room.

4.4.10. Split Plane Maneuvering. Split plane maneuvering within the visual merge is paramount—not only for trying to achieve the required turning room, but also to make it easier to assess bandit intentions. It is essential to constantly assess the bandit's nose position and POM to determine whom the bandit is attempting to engage. If it is ever determined that the bandit's nose is turning to threaten the supporting fighter, transition to a defensive mindset and deny any potential bandit WEZ. Achieving this vertical turning room can be done high or low. The advantages and disadvantages of each may be situation dependent and all factors must be considered, including: current energy states, visual acquisition, IRCM/adverse backgrounds, fight dynamics, etc. Regardless of the direction chosen, maneuvers to get out-of-plane need to be aggressive and expeditious. The turning room required is also situation dependent. Energy states, G available, ordnance capability, aspect, and HCA all need to be considered when deciding “that's enough”. It is usually safe to assume that the bandit will turn roughly the same number of degrees, as you will during the turn to point. There is nothing worse than thinking there is turning room only to arrive inside minimum range of your ordnance.

4.4.11. Entries. The engaged fighter's proximity to the bandit, and weapon FOV, will dictate when the supporting fighter needs to maneuver for an entry or a shot of opportunity. The supporting fighter, when not offered a shot of opportunity, should be able to maneuver to the control position at the role exchange.

4.4.11.1. Entry Communications. If the engaged fighter asks for assistance, (“VIPER ONE, NEUTRAL”). The supporting fighter communicates a willingness to engage and position from the fight (i.e., “VIPER TWO, ENGAGED, LOW - NORTH”). The engaged fighter reaction should be to acknowledge the radio call immediately with “PRESS,” “CLEARED,” or “NEGATIVE.”

4.4.11.1.1. “NEGATIVE” replies. The engaged fighter should respond with “NEGATIVE” if able to maneuver to employ ordnance; will traverse through the control zone; and does not want the supporting fighter to enter and become engaged.

4.4.11.1.2. “CLEARED” replies. If the engaged fighter “CLEARS” the supporting fighter to enter, the new ***engaging*** fighter continues to the offensive position (control zone) while retaining deconfliction responsibility. No role change has occurred—supporting role is still maintained. The engaged fighter will need to continue to maneuver (normally away from the control zone) until the supporting fighter kills the bandit; a role exchange is appropriate or maneuver to kill the bandit (i.e., re-engage).

4.4.11.1.3. “PRESS” replies. If the engaged fighter tells the supporting fighter to “PRESS,” the role exchange occurs and the previously engaged fighter now assumes the supporting role.

4.4.11.2. Entry Techniques. There are two types of entries: from the vertical (above or below) or from outside the bandit's Tc. The supporting fighter can enter from outside from Co-Flow (turning in the same direction as the bandit) or Counter-Flow (turning in the opposite direction of the bandit) geometry. Both entries require vertical turning room to be most effective. While maneuvering for an entry always be alert for shots of opportunity.

4.4.11.2.1. Vertical Entry. The vertical entry occurs when the supporting fighter is directly above or below the fight. This entry requires a large altitude Delta, and may be effective because it is difficult for the bandit to keep track of the supporting fighter. If attempting a vertical entry from low to high, be aware that the fight is often descending, and additional turning room may be required to complete a conversion.

4.4.11.2.2. Entry from Outside the Tc. The other type of entry is from the outside of the bandit's Tc. The supporting fighter gets to this position either because he is outside the bandit's Tc at the initial merge or because he passed through the Tc after the fight started. There are two types of outside entries: Co-Flow and Counter-Flow.

4.4.11.2.2.1. Co-Flow Entry. As shown in **Figure 4.71., **Co-Flow Entry, both the supporting fighter and the bandit are turning in the same direction. The supporting fighter can get a Co-Flow entry if he is outside the bandit's Tc as the bandit's extended 3/9 line passes through the aircraft. As the bandit continues the turn, the supporting fighter must increase aspect to defend against a possible bandit switch. This will set him up for the entry. For this entry to work, the supporting fighter has to be split plane with the bandit. If the supporting fighter is in plane, the bandit will probably maintain tally on the supporting fighter. As both the bandit and the supporting fighter turn, the supporting fighter will have to react defensively to the bandit's nose position. Any geometry for entries or shots of opportunity will be lost. A visual cue for the supporting fighter to start his turn is either the passage of the bandit's 3/9 line or as the bandit enters a potential WEZ.

4.4.11.2.2.2. Counter-Flow Entry. As shown in **Figure 4.72., **Counter-Flow Entry, the supporting fighter's turns are opposite the bandit's. The major difference between the Co-Flow and Counter-Flow Entries is the frequency at which an entry opportunity occurs. Since the supporting fighter is flying in the opposite direction the fight is turning, the bandit's 3/9 line will pass through him more often than in a Co-Flow entry. The supporting fighter must strive for lateral and vertical offset quickly. Insufficient altitude Delta may allow a bandit tally, and force a defensive reaction from the supporting fighter. The visual cue for the supporting fighter to start the turn occurs earlier than for the Co-Flow Entry. The turn should be initiated after the bandit's nose passes, but before 3/9 line passage. The supporting fighter may begin to turn earlier, if there is more range (i.e., at longer ranges turn slightly after the bandit's nose passes, at closer ranges turn as the bandit's 3/9 is passing).

4.4.12. Role Exchanges. Role changes must be positive, clearly communicated, and properly executed by ***both*** fighters or grave consequences will arise. Aircraft continue to try to occupy the same space if two fighters are trying to offensively engage the same bandit simultaneously. During ACM with mutual support, the engaged fighter is maneuvering to employ ordnance, and the other fighter is supporting him. Prolonged turning engagements will only decrease the flight members' SA and could jeopardize survival. The supporting fighter should actively work for a shot of opportunity.

4.4.12.1. Frequency. Role exchanges are not normally required during ACM. If the engaged fighter is offensive and subsequently becomes neutral, the supporting fighter should usually be able to kill the bandit quicker with a shot of opportunity instead of a role change. If the supporting wingman needs a role change to kill the bandit (i.e., only the gun is available) request to be "ENGAGED." For the supporting flight lead, become the engaged fighter with an "ENGAGED" call. The critical word to communicate a role change is "PRESS." Until the currently engaged fighter says "PRESS," the supporting fighter retains deconfliction responsibility.

Figure 4.71. Co-Flow Entry.

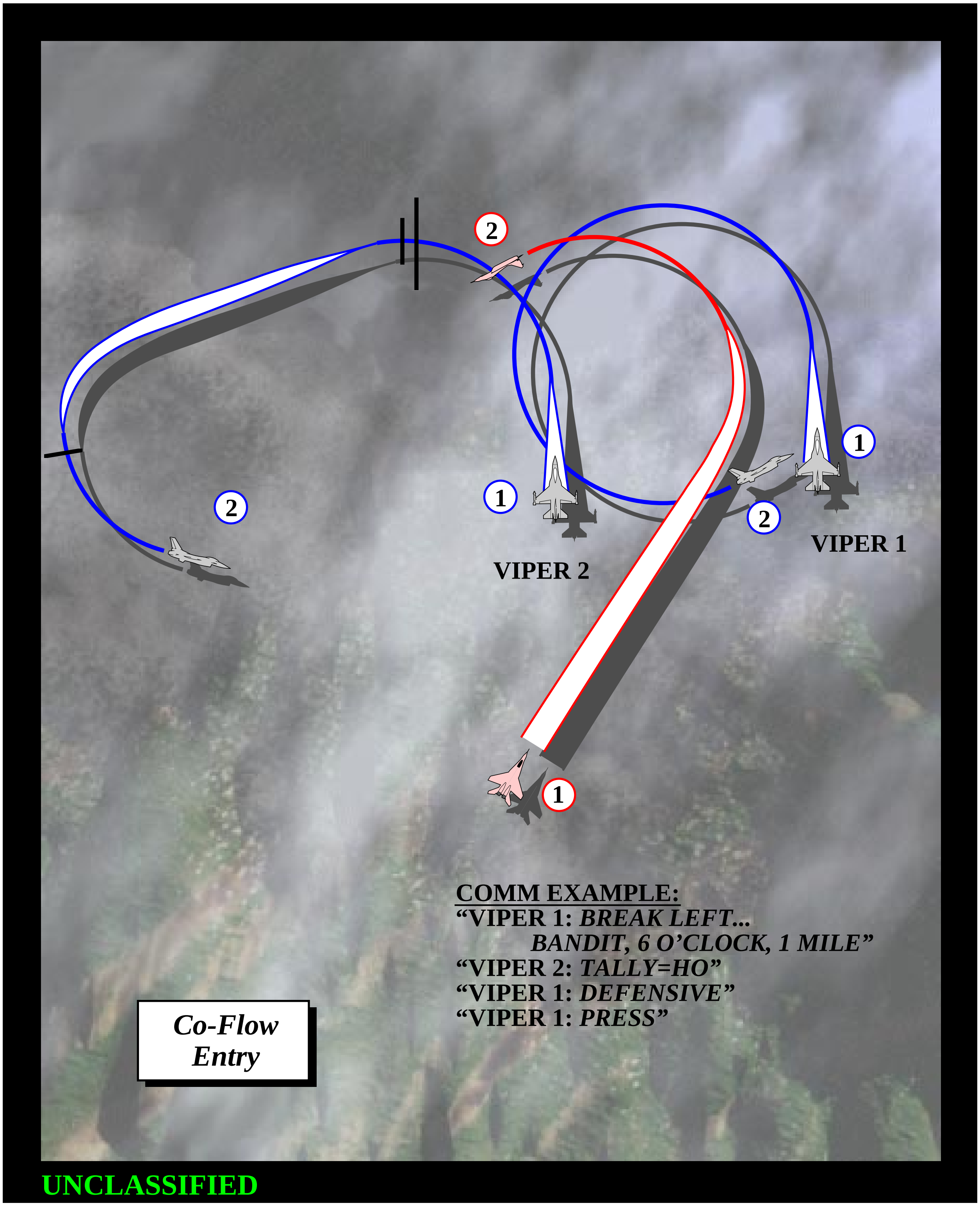
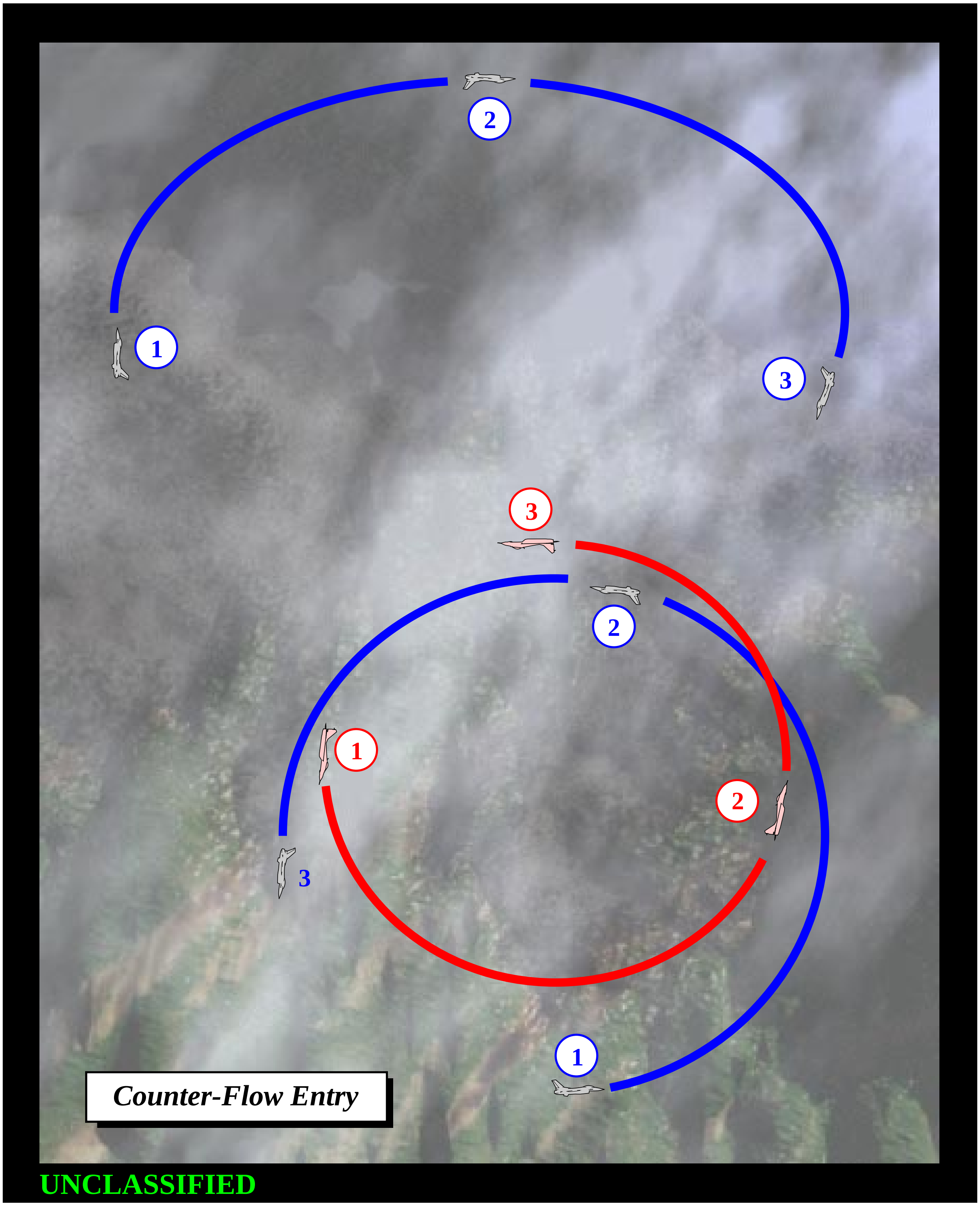


Figure 4.72. Counter-Flow Entry.



4.4.12.2. Defensive. The one time a role change will always happen is if the supporting fighter becomes defensive. When a supporting fighter calls “DEFENSIVE” he is immediately relieved of deconfliction responsibility after acknowledgement. The other fighter, either engaged or supporting, must acknowledge and assume deconfliction for the flight. This may dictate exiting the control zone and seeking an entry, if the visual is not immediately acquired. If a “DEFENSIVE” call is not promptly acknowledged, it is essential to repeat the call to ensure the other fighter realizes new responsibilities. Until the engaged fighter acknowledges the “DEFENSIVE” transmission (“PRESS” or “VISUAL”), the previously supporting fighter retains deconfliction.

4.4.12.3. “CLEARED” Example. In this case Viper One called “CLEARED,” Viper Two continues to the control position and provides Viper One with the visual. The role change is complete only when the currently “ENGAGED” fighter transmits “PRESS”. The previously engaged fighter cannot simply disregard the bandit during this phase. The engaged fighter must still maneuver in relation to the bandit until the bandit either blows up, or is no longer a factor (i.e., the bandit honors the supporting fighter's threat, or disregards the disengaging fighter and attempts to extend from the fight). Flight members must thoroughly understand these roles and, most importantly, how to change roles, especially in a degraded communication environment or if the visual can not be maintained. (See **Figure 4.73.**, Role Exchange, **Table 4.5.**, Examples of ACM Role Change**,** and **Table 4.6.**, Example of Supporting Fighter Becoming Defensive.)

4.4.13. Egress. The supporting fighter will frequently be in the best position to call the egress after the bandit is dead. The first consideration is to get the flight moving quickly away from the fireball. The direction should be based on the post-merge flow plan, if able (ground-controlled intercept [GCI] calls may be very useful at this time). Consideration should also be given to a large change in altitude as the flight egresses. Initially the flight should fly the egress heading without regard to precise formation position. Visual and radar warning receiver (RWR) cross-check are crucial at this time. Additionally the flight members should strive to sanitize with the radar as briefed. Generally, ACM slewable followed by short range RWS works well. Once the flight is well clear of the fireball, lead will direct the formation as appropriate.

4.4.14. 2v1 Offensive Visual Maneuvering. In an offensive situation typically the flight lead will be the engaged fighter—the wingman can be the engaged fighter if he has the only tally or is in a better position to attack, etc. The engaged fighter must fly his best BFM to kill the bandit and remain offensive. The engaged fighter should also inform the supporting fighter of changes in status (i.e., becomes neutral). The supporting fighter must maneuver as required to not become defensive and help kill the bandit quickly. Split plane maneuvering will help the supporting fighter do both of these things. As the supporting fighter looks for shots of opportunity CAF must be carefully evaluated. If the engaged fighter transitions from offensive to neutral the supporting fighter usually will not require a role exchange to kill the bandit. The keys to success for the supporting fighter are aggressive split plane maneuvering (to avoid bandit tally ho) and quick recognition of available shots of opportunity.

Figure 4.73. Role Exchange.

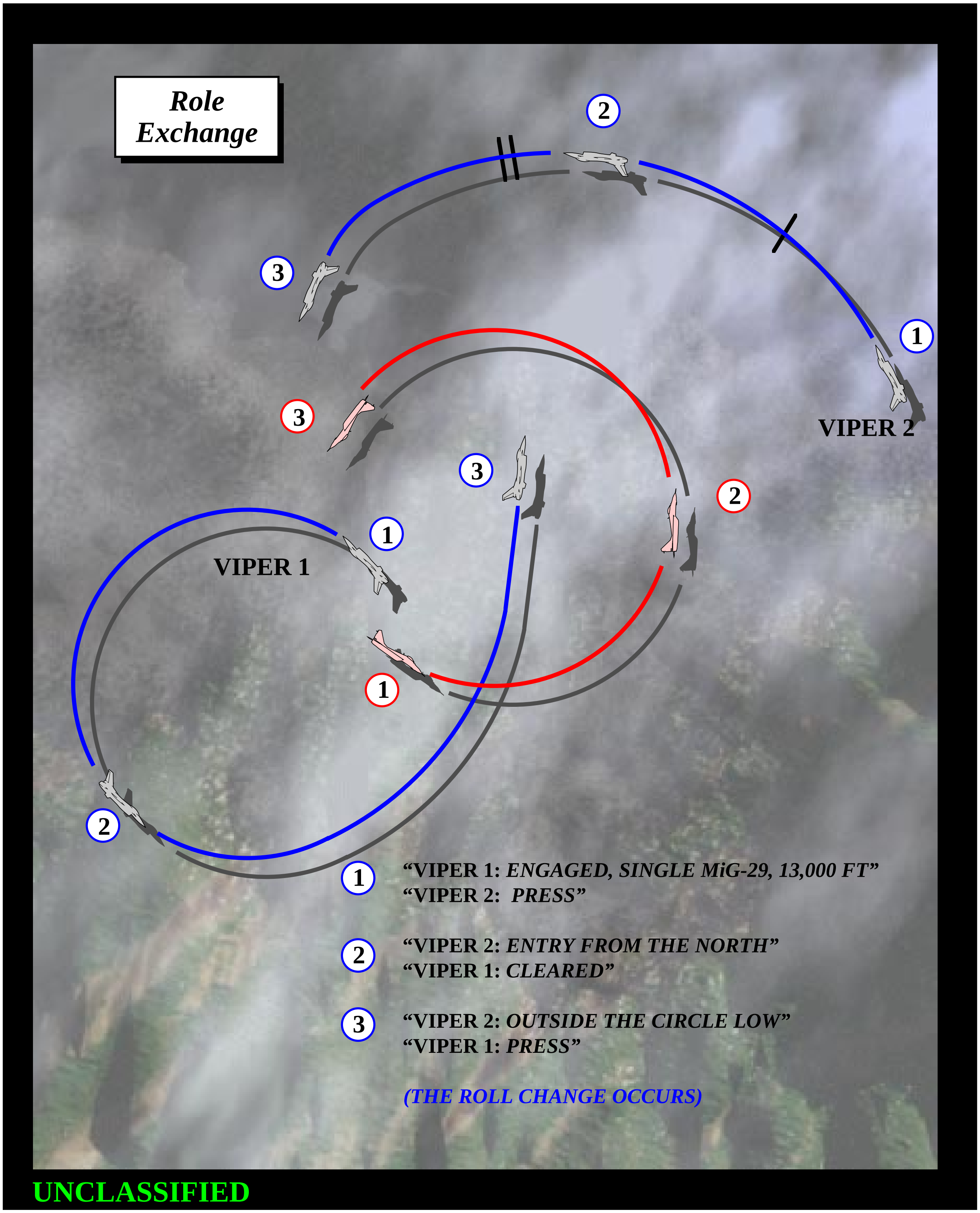


Table 4.5. Examples of ACM Role Changes.

Examples of ACM Role Changes
Lead: “Viper 1 tally Bogey, 12 o’clock, 5 miles, slightly low.” Give descriptive information to help wingman get the tally, never just say “Tally”
Lead: “Viper 1 Engaged, bull 180/10, 15 thousand.”
Wing: “Viper 1 Press.” Informative call from wingman assuming supporting role.
Lead: “Viper 1 Engaged Neutral.” Informative call from lead that he is no longer offensive. The wingman should be maneuvering for a shot of opportunity. If he cannot get a shot of opportunity or wants to request a role exchange he should call that he has an entry.
Wing: “Viper 2 has an entry from west high.” (or outside/inside/etc.; used if role swap/ ”control zone” entry is required.)
Lead: “Viper 2 Cleared” or “Negative,” or “Press,” as appropriate; if Viper 1 says “Cleared,” Viper 2 is still responsible for deconfliction until Viper 1's “Press” call. Role change is complete at the “Press” call. The wingman is not required to call engaged. If he does it is advisory only. The role change is already complete at the press call. In this example lead give also give the wingman his intentions with the press call (i.e., “Viper 2 Press, 1's coming off low outside”).
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Table 4.6. Examples of Supporting Fighter Becoming Defensive.

Examples of Supporting Fighter Becoming Defensive
Lead: “Viper 1's Engaged bull 180/10 15 thousand.” Wing: “Viper 1 Press” …some bad ACM maneuvering follows… Wing: “Viper 2's Defensive.” Automatic role change. When #2 calls defensive he is relieved of deconfliction responsibility.
NOTE: At this point it is possible that Viper 1 and Viper 2 will be blind on each other. For example: If Viper 1 is engaging the Bandit it is always possible that he will lose sight of Viper 2 (the supporting fighter). If Viper 2 calls defensive he drops the supporting fighter role and maneuvers exclusively to defend himself. It is critical that Viper 1 acknowledge Viper 2's defensive call. If Viper 1 is blind on Viper 2 he must immediately communicate as required to ensure denconfliction.
Lead: “Viper 1 Blind.” Acknowledgement of Viper 2's defensive call. Wing: “Viper 2's on the bandit's nose for 1 mile, low.” Lead: “Viper 2 Press.” Viper 1 is providing visual mutual support.
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4.4.15. 2v1 Defensive Visual Maneuvering. There are four priorities which the element must satisfy in order to survive a defensive situation. They are detection, negating the threat, maintaining flight integrity and mutual support through role execution, and lethal weapons employment against the bandit.

4.4.15.1. Initial Attack. When the flight finds itself under attack, the obvious concern is survival (negating the bandit's initial attack). Because fractions of a second are very important, the flight must have some preplanned initial moves; actions that they are very familiar with and have thoroughly practiced. The bandit's intentions may not be initially apparent, so it is important that each fighter assumes he is under attack.

4.4.15.2. Bandit Detection. When the bandit is located (dependent on range and relative position), either split the element laterally and vertically and increase airspeed, or perform a hard turn or break turn into the bandit. A hard turn is used when the bandit is not yet in range to employ ordnance. A "BREAK" turn is used when you locate the threat and someone is in a WEZ. If unsure, call for a "BREAK" turn. The directive call for a break turn implies that onboard countermeasures will also be automatically employed, (i.e., chaff and flares are expended). Never make any initial moves just so your wingman will get a quicker shot, (i.e., dragging the bandit at your 6 o'clock, holding the bandit off, using yourself as bait—***defend yourself now***!) Never depend on assistance from the outside to ***survive*** an attack! Radio calls will normally initiate any move the formation takes. The key to effective communication is to transmit the information ***in order*** using directive then descriptive comments, as discussed earlier. Attempt to assess which fighter the bandit is trying to attack.

4.4.15.2.1. Principles for Success. When defensive, avoid putting both aircraft in the same area at the same time. When possible, utilize split plane maneuvering. The main principles to follow in accomplishing initial moves when the bandit is sighted in the aft quadrant (WEZ available):

4.4.15.2.1.1. The pilot with the tally should always:

- Do sound BFM by starting a hard/break turn into the bandit.
- Direct the flight to turn (left or right).
- Dispense chaff and flares if threatened.
- Talk element mate's eyes onto the bandit.

NOTE: An attempt should be made to accomplish all of the above items simultaneously.

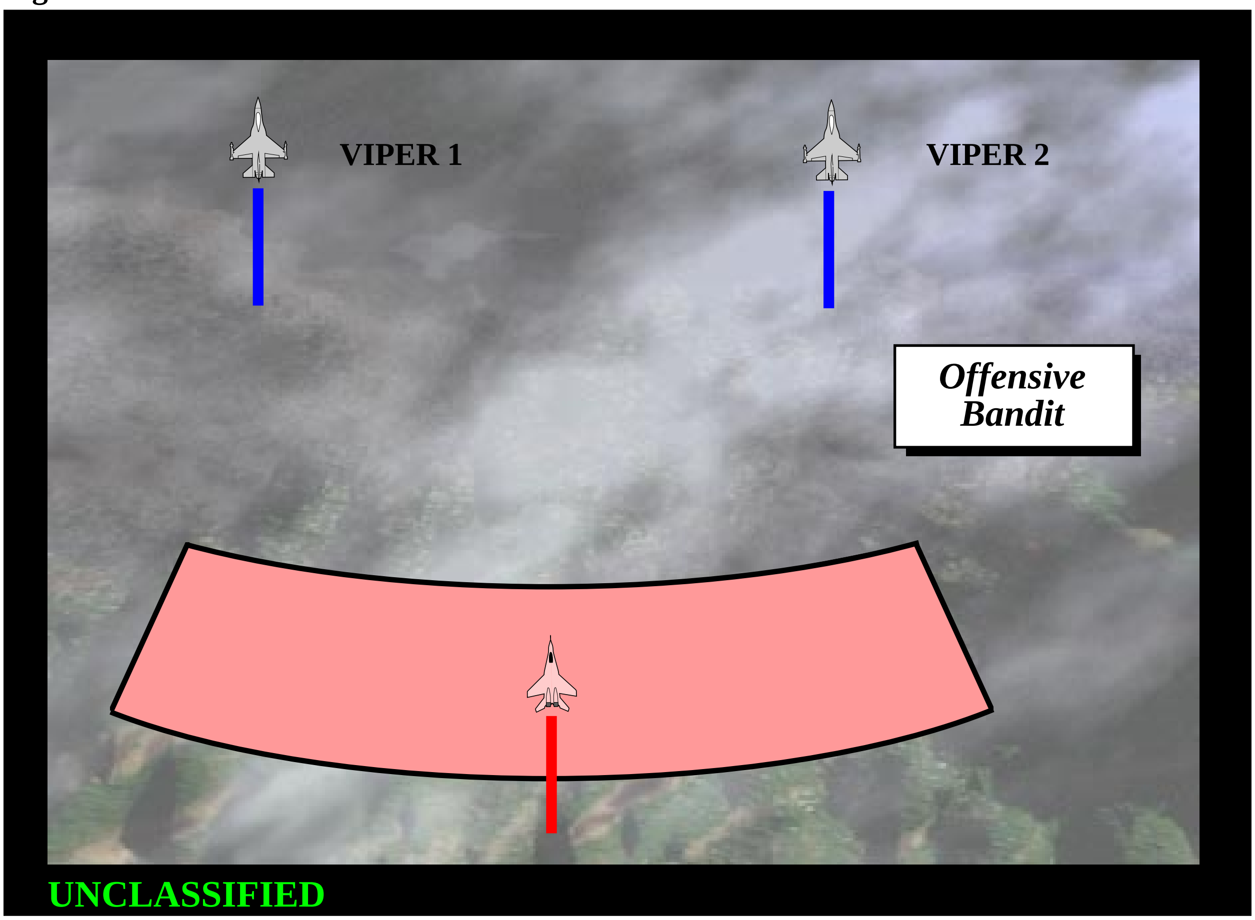
4.4.15.2.1.2. The pilot without the tally should:

- Perform the turn directed in the direction called.
- Dispense chaff and flares.
- Attempt to acquire the tally.

4.4.15.2.2. Loss of Visual. If both fighters are blind, it is imperative that roles be established. Both fighters (to ensure friendly flight path deconfliction) must accomplish positive communication and effective maneuvering. The flight lead is ultimately responsible for establishing these roles, element survival, and training rule compliance. References off the bandit and/or separate altitudes to ensure deconfliction will help both fighters achieve the visual while increasing SA.

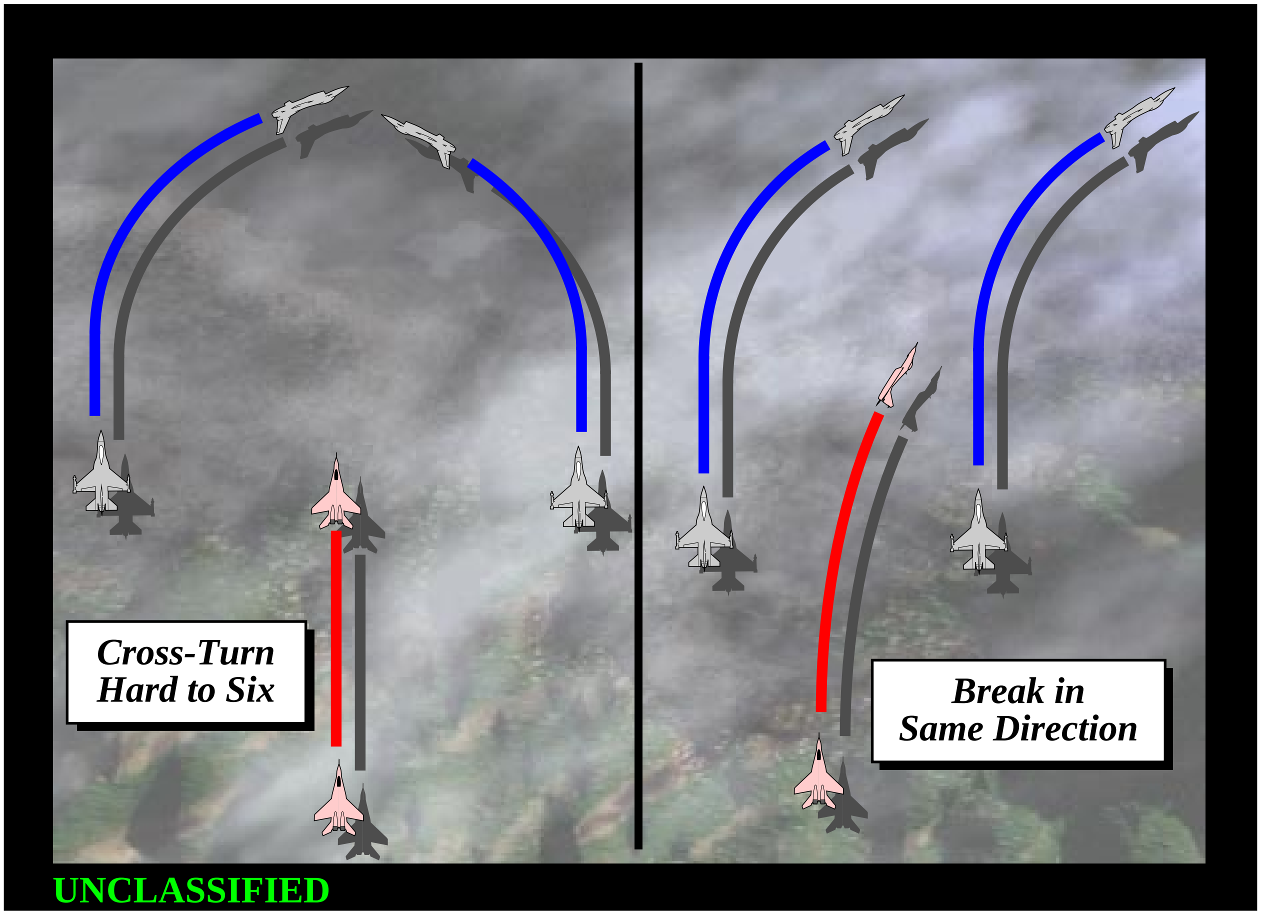
4.4.16. Initial Moves. The bandit's position may not clearly identify the F-16 under attack. The bandit can come from any aspect. A quick assessment of the bandit's lethality must be made based on range and nose position. If the bandit has not reached a WEZ, an extension (while monitoring the bandit) may be appropriate. If the bandit is a threat, or continues to close, a prompt flight reaction is required. This discussion addresses the principles valid for all potential bandit attack axes. The initial move should accomplish five things: deny a shot, present the bandit with maximum BFM problems, force the bandit to commit on one or the other fighter, maximize the element's offensive potential after the initial move, and clearly establish engaged and supporting fighter roles if the bandit arrives as shown in **Figure 4.74.,** Offensive Bandit. The bandit can engage either fighter and maintain 3/9 and the offensive role. The element has two choices in their initial defensive reaction:

Figure 4.74. Offensive Bandit.



4.4.16.1. Break Together (Same Direction). The first option is to break the element in the same direction as shown on the right of **Figure 4.75.,** Fighter Options. This is the preferred option if the bandit is detected outside of weapons parameters, or has not yet closed inside either fighter's Tc. If the bandit is allowed to close to either (or both) fighter's Tc, the bandit will probably be able to employ ordnance prior to the reaction being effective. Visual lookout is the key to preventing this from happening.

Figure 4.75. Fighter Options.



4.4.16.1.1. Advantages.

- Fighters are able to gain/maintain tally throughout the turn.
- The bandit's intentions will become apparent.
- Bandit offensive potential versus each fighter is no longer identical.
- Each element member can isolate the threat axis on the same side of their respective aircraft.
- The element is in a position to establish defensive and supporting fighter roles based on bandit reaction. The defensive fighter can devote full attention to his best 1v1 BFM. The supporting fighter can easily direct the defensive fighter to react and gain the tally.

4.4.16.1.2. Disadvantages.

- The no-joy fighter may have to maneuver without tally during the initial part of the turn.
- The bandit has a possible shot opportunity as both fighters react.

4.4.16.2. Break Opposite. The second option is to break the element toward each other in a cross-turn or hard-to-six turn. This option is more difficult to execute, because both fighters must ensure deconfliction while maneuvering against the bandit. If the bandit is allowed to close before being detected, the cross turn option may make it easier for both fighters to gain the tally. At shorter ranges the bandit will have a WEZ on both fighters, and engagement intentions will become apparent more quickly.

4.4.16.2.1. Advantages:

- Each fighter maximizes the BFM problem for the bandit.
- Neither fighter rotates vulnerable cone through the bandit's position.
- Both fighters have an increased probability of maintaining tally.

4.4.16.2.2. Disadvantages:

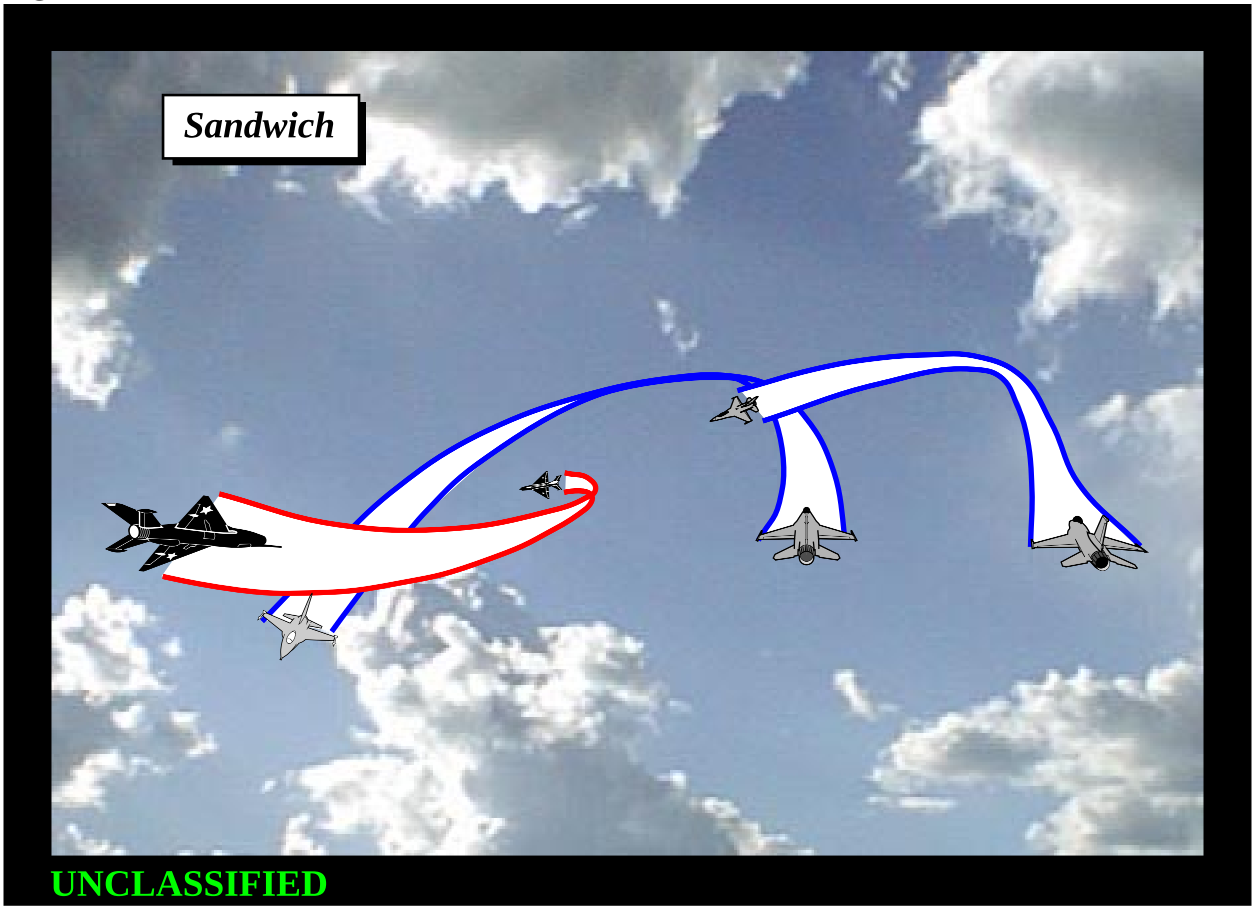
- The bandit's decision to commit can be delayed until closer to (and perhaps inside) both fighter's Tc.
- The bandit may be able to meet one fighter at high aspect and isolate both fighters on one side of the aircraft.
- The assignment of defensive and supporting fighter roles within the element is delayed.
- If both fighters perform hard/break turns in the bandit's POM, the potential for flight path conflict increases.

4.4.17. Follow-On Maneuvering. After the initial break is accomplished the bandit must decide whom to engage: engage the front fighter in the break (no switch); immediately engage the trail fighter (early switch), or enter the front fighter's Tc then switch to the trailer (late switch).

4.4.17.1. No Switch. The bandit decides to stick to the front fighter. This is usually caused by the bandit being unaware of the other fighter. If the bandit continues this attack, the supporting fighter should sandwich and kill him. As shown in **Figure 4.76.,** Sandwich, the "sandwich" is an ideal defensive maneuver and should allow the supporting fighter an opportunity to achieve weapon parameters and kill the bandit. It is critical for the supporting fighter to maintain maximum rate and the smallest Tc available to maintain a WEZ.

4.4.17.2. Early/Late Switch. If the bandit is aware of both fighters, a "switch" is probable. The switch must be communicated so the defensive and supporting roles can be fulfilled and deconfliction can be assured. (See **Figure 4.77.,** Switches.) An early switch (bandit switch prior to Tc entry) will enable the initially no-joy/defensive fighter to change to a constant turn defense, or extend, since the bandit's nose will come off to threaten the other fighter. The constant turn allows the supporting fighter to back off on the turn rate to maintain energy, keep the bandit in sight, and continue to rotate the vulnerable area away from the bandit while offsetting the Tc and looking for an entry or shot of opportunity. The extension attempts to regain tactical maneuvering airspeed and maximize split plane maneuvering before attacking the bandit. In either case, the supporting fighter must take the quickest shot of opportunity available. A late switch (bandit switch inside the Tc) may allow the supporting fighter to meet the bandit at high aspect. This depends on the bandit and defender's BFM. If the fighter meets the bandit close aboard, normally an engaged call and a one-circle fight is appropriate. In this case, the other fighter will become the supporting fighter and look for an immediate shot of opportunity.

Figure 4.76. Sandwich.



4.4.18. High-Aspect Air Combat Maneuvering. An optimum entry against a high-aspect threat is one that allows the element to identify the threat and bring ordnance to bear quickly. The primary formations for engaging a high-aspect threat are from the visual bracket or WEZ in-depth.

4.4.18.1. Visual Bracket. The end result spreads out the formation to 3 to 4 NM (or visual limits), and allows the flight to maintain visual mutual support and determine bogey intentions. (See **Figure 4.78.,** Visual Bracket.) Communications are critical to determine which fighter the bogey is attempting to engage. A combination of RWR and radar awareness is critical. As the flight lead analyzes aspect and continues to the merge performing a single-side offset intercept, the wingman maneuvers away from the flight to obtain turning room and a vertical separation. At 5 NM the flight lead should go pure pursuit. If the bogey leans on the flight lead, the wingman should have an easy shot of opportunity at the merge. To be effective, the wingman needs to anticipate this shot, and start leaning in to be pointing at the bogey at the merge. After the flight lead passes the identification, the wingman should be able to take a quick shot of opportunity. If the bogey initially leans on the wingman, lead may clear the wingman to engage or remain the engaged fighter. If the bandit points toward the wingman, the wingman will arrive at the merge first. With SA, the wingman should pass the WEZ in-depth (WID) so that the flight lead can employ weapons.

Figure 4.77. Switches.

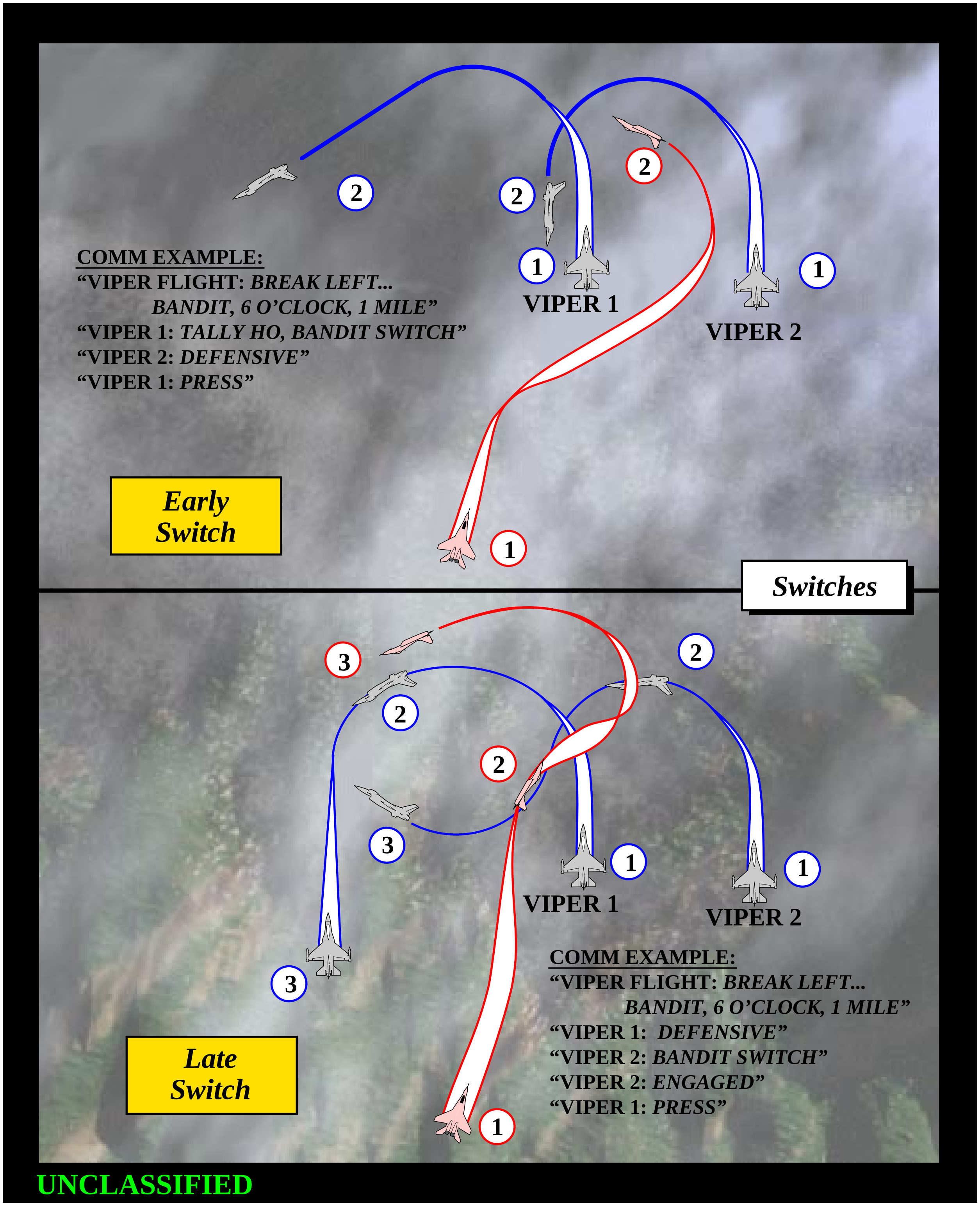
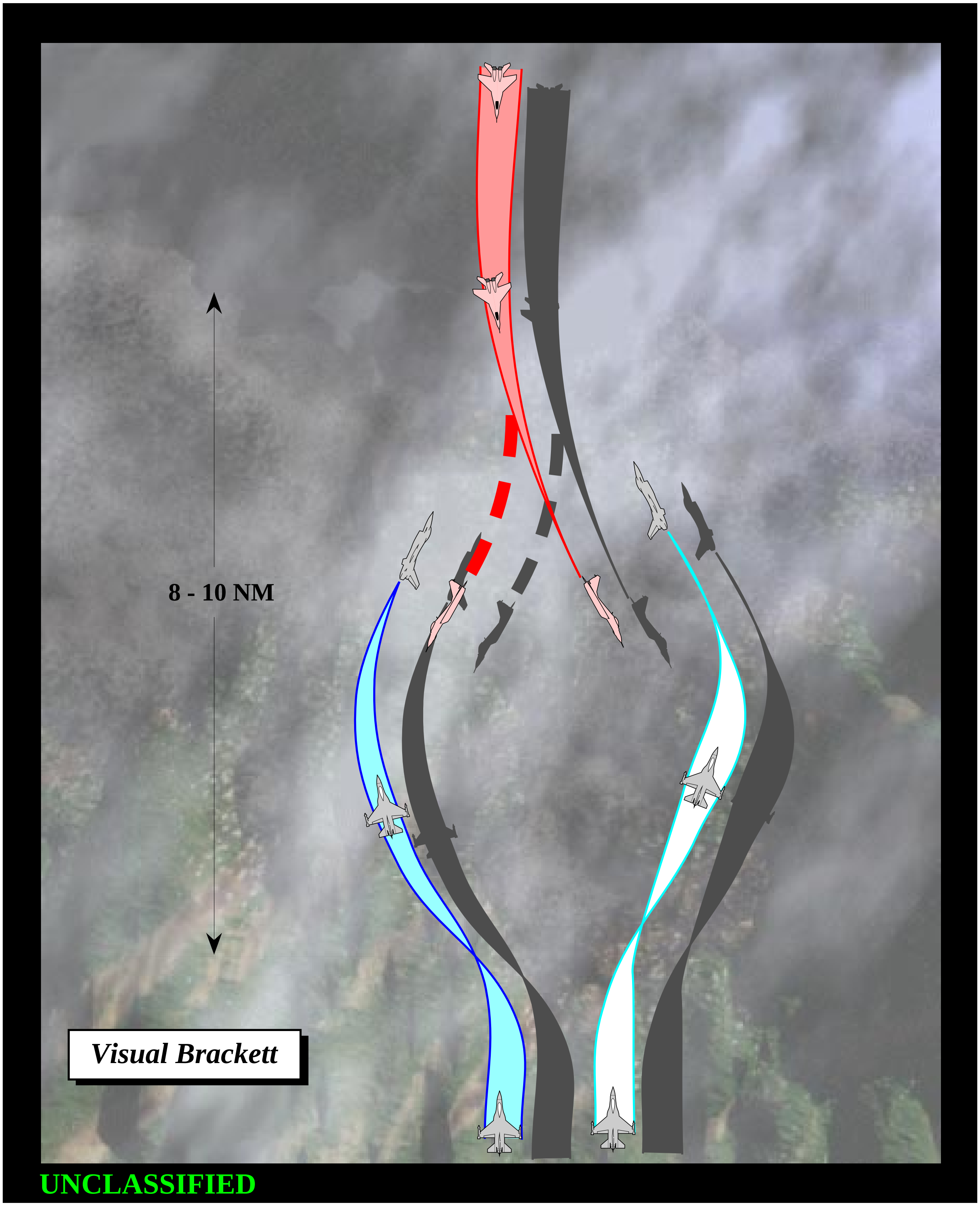


Figure 4.78. Visual Bracket.

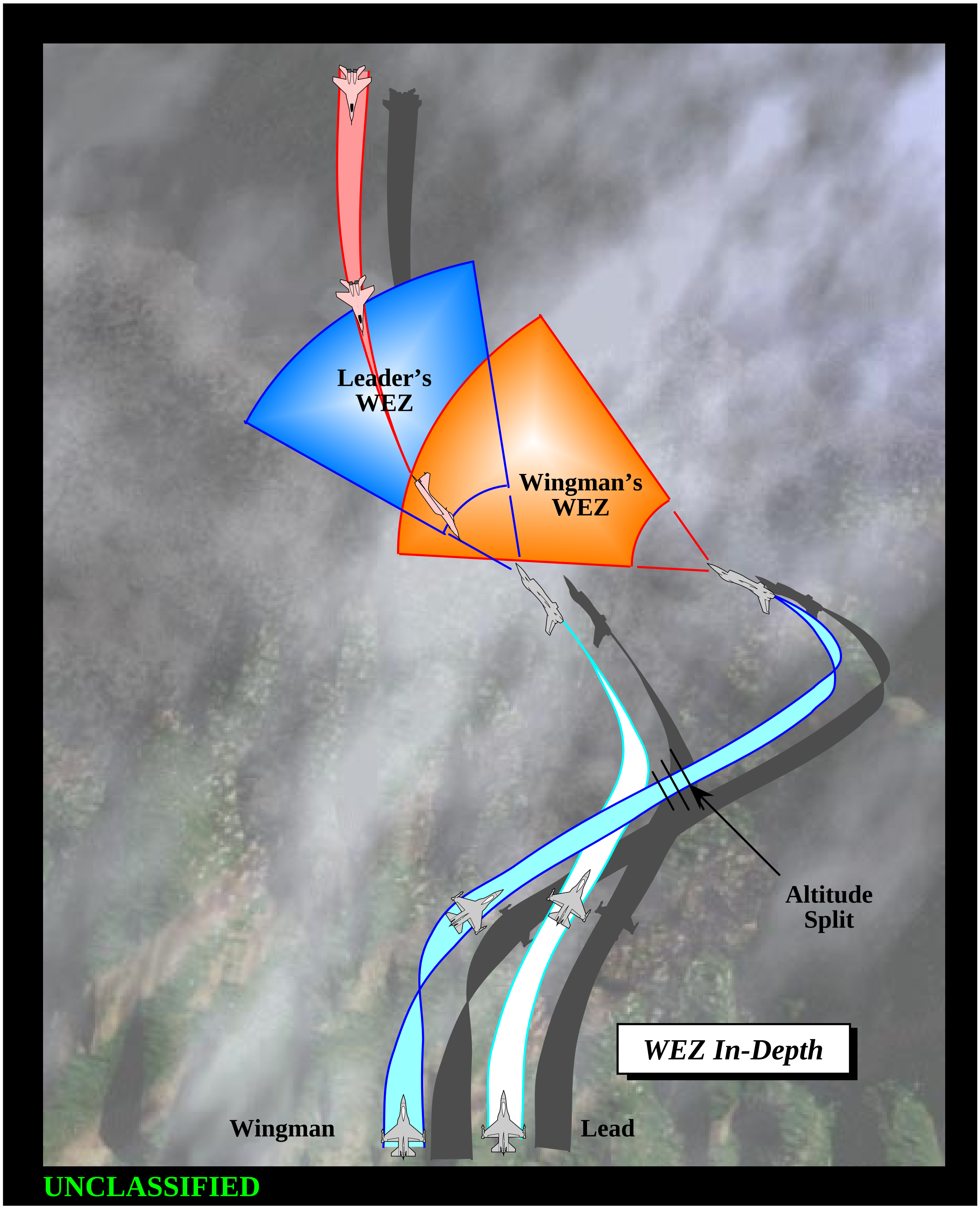


4.4.18.2. WEZ In-Depth. As shown in **Figure 4.79.,** WEZ In-Depth, depicts a formation that allows for a quick kill versus a high-aspect bogey. The wingman's most challenging job will be to maintain visual while maintaining the proper formation. WID can be achieved in numerous ways, but the primary consideration is maintaining enough separation to preserve the wingman's WEZ at the merge. Other important considerations include ensuring CAF and split plane maneuvering to avoid giving up bandit tally-ho's. Normal wingman positioning occurs after the flight lead takes offset described in **paragraph 4.5**, Intercepts, and allows maneuvering within a cone 1.5 to 3.0 NM spacing, from 30 to 60 degrees aft.

4.4.19. Air Combat Maneuvering in Multi-Bandit Scenarios. ACM versus a single bandit is truly the building block for multi-bandit scenarios. All of the basic ACM contracts and roles will still apply, but there are several more considerations. If more than one bandit survives the initial merge the element must maneuver aggressively to kill the bandits quickly. It is imperative that the supporting fighter be able to rapidly assess and take shots of opportunity, while retaining deconfliction responsibilities. The supporting fighter must not sacrifice visual mutual support unless directed, or it is required to prevent becoming defensive. If the supporting fighter is forced to sacrifice visual, communicate this immediately with a split or blind call. If the supporting fighter is forced to split to a bandit in the same visual merge, it is possible to have two 1v1 engagements in close proximity. Ideally, at least one of the fighters will be visual and able to deconflict from the other. If this is not possible, lead must be directive to ensure deconfliction in any manner appropriate to the situation. Additionally, both fighters must remain alert for shots of opportunity into the other fight, as well as for shots from the other bandit.

4.5. Intercepts. An intercept is the series of maneuvers, using a GCI, Airborne Warning and Control System (AWACS), on-board systems, or dead reckoning (DR), which places the aircraft in a position from which a weapon may be employed, visual identification (VID) can be made, or a visual engagement can be initiated. The tactical decision to "commit" to an intercept is based on guidance and criteria established in MPM. The type of intercept geometry utilized is based on experience, proficiency, avionics, weather, night, electronic countermeasures (ECM) and tactical considerations. This section will review intercept basics and the baseline intercept. Some tactical considerations will also be discussed, however reference to AEM, Volume 5 is necessary for a complete understanding of tactical intercepts.

Figure 4.79. WEZ In-Depth.



4.5.1. Intercept Basics. In the F-16, the intercept problem involves using the radar to detect a specific target, then using geometry to arrive at a position from which the target can be identified (if required) and weapons fired. (See **Figure 4.80.,** Intercept Basics.) To achieve this, the fighter pilot must accomplish these tasks:

- Close on the target.
- Establish identification (may be a continuous process).
- If a beam or stern conversion is required, acquire sufficient displacement from the target (room for the conversion turn).
- Go pure pursuit.
- Obtain a tally.
- Establish a VID, if required.
- Maneuver to weapons parameters.

4.5.2. Baseline Intercept. A popular technique for accomplishing these steps is the baseline intercept. This is the foundation upon which more complicated tactical game plans are built. Before discussing the baseline intercept, a few intercept terms will be reviewed.

4.5.3. Intercept Terminology. A thorough knowledge and understanding of BFM principles and geometric terms will aid in intercept execution.

4.5.3.1. Aspect Angle (AA): The angle between the longitudinal axis of the target (projected rearward) and the LOS to the fighter, measured from the tail of the target. The fighter's heading is not a consideration. (See **Figure 4.1.,** Geometric Relationships.)

4.5.3.2. Antenna Train Angle (ATA): This is the angle between the nose of the fighter and the radar LOS to the target. ATA is referenced in degrees left or right of 0 degree azimuth on the MFD. (See **Figure 4.1.,** Geometric Relationships.)

4.5.3.3. Collision Antenna Train Angle (CATA): CATA is the azimuth of the radar antenna when tracking a target that is on a collision course with the fighter. This is the fighter's quickest route to an intercept/collision/tally with the target. A target on a collision course drifts straight down the MFD. Its azimuth never changes. An easy way to determine CATA for a co-speed target is to subtract AA from 180 degrees. For example, the CATA for a target with a 150-degree AA is 30 degrees (180 to 150 degrees). Angular relationships are shown in **Figure 4.81.,** Collision Antenna Train Angle.

4.5.4. The Baseline Intercept. This section will provide a very basic and simple review of the baseline intercept. For this discussion, it is assumed that the intent is to acquire some turning room (offset) to complete a conversion turn to the target's beam or stern. There are five steps in the baseline intercept:

Figure 4.80. Intercept Basics.

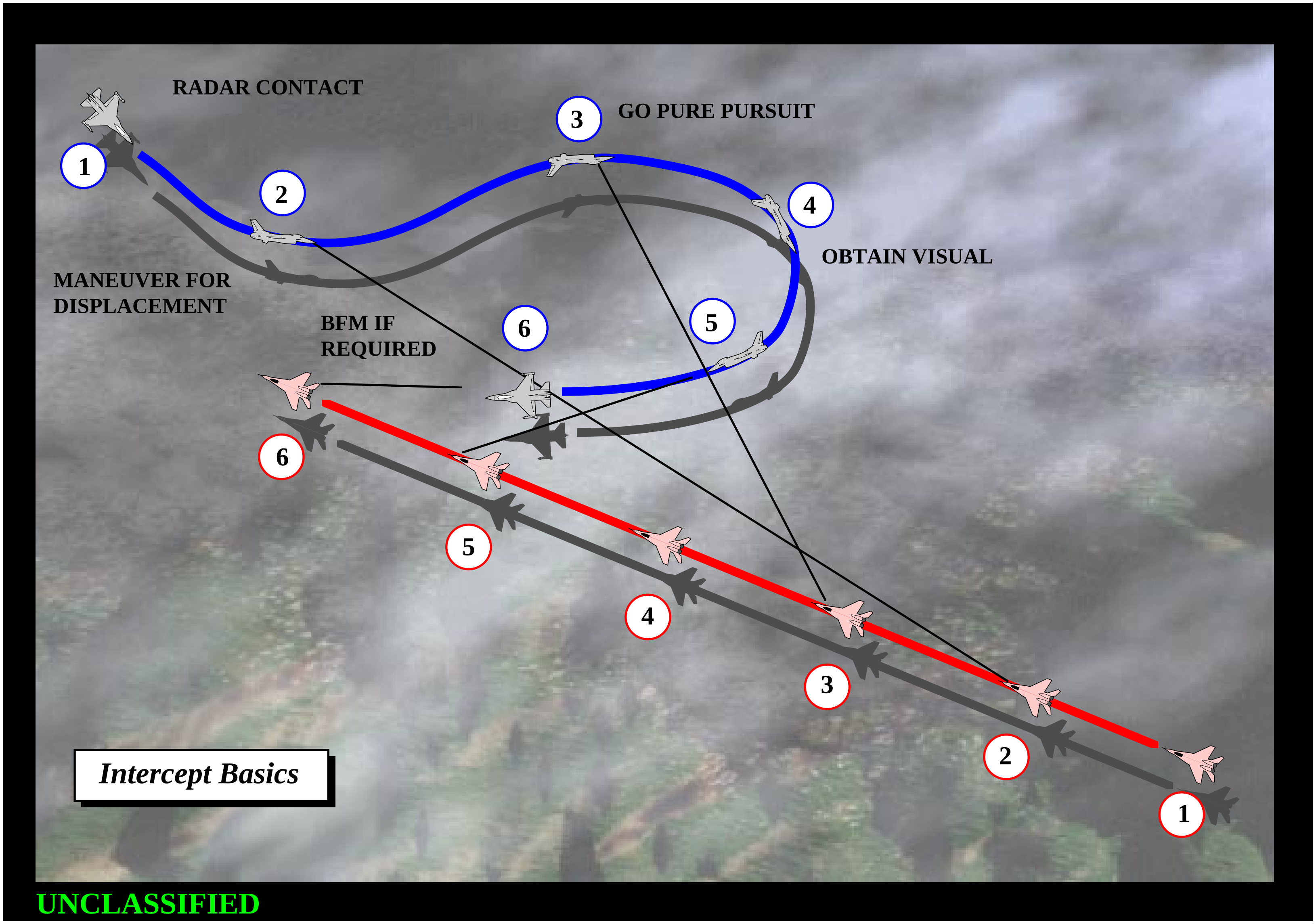
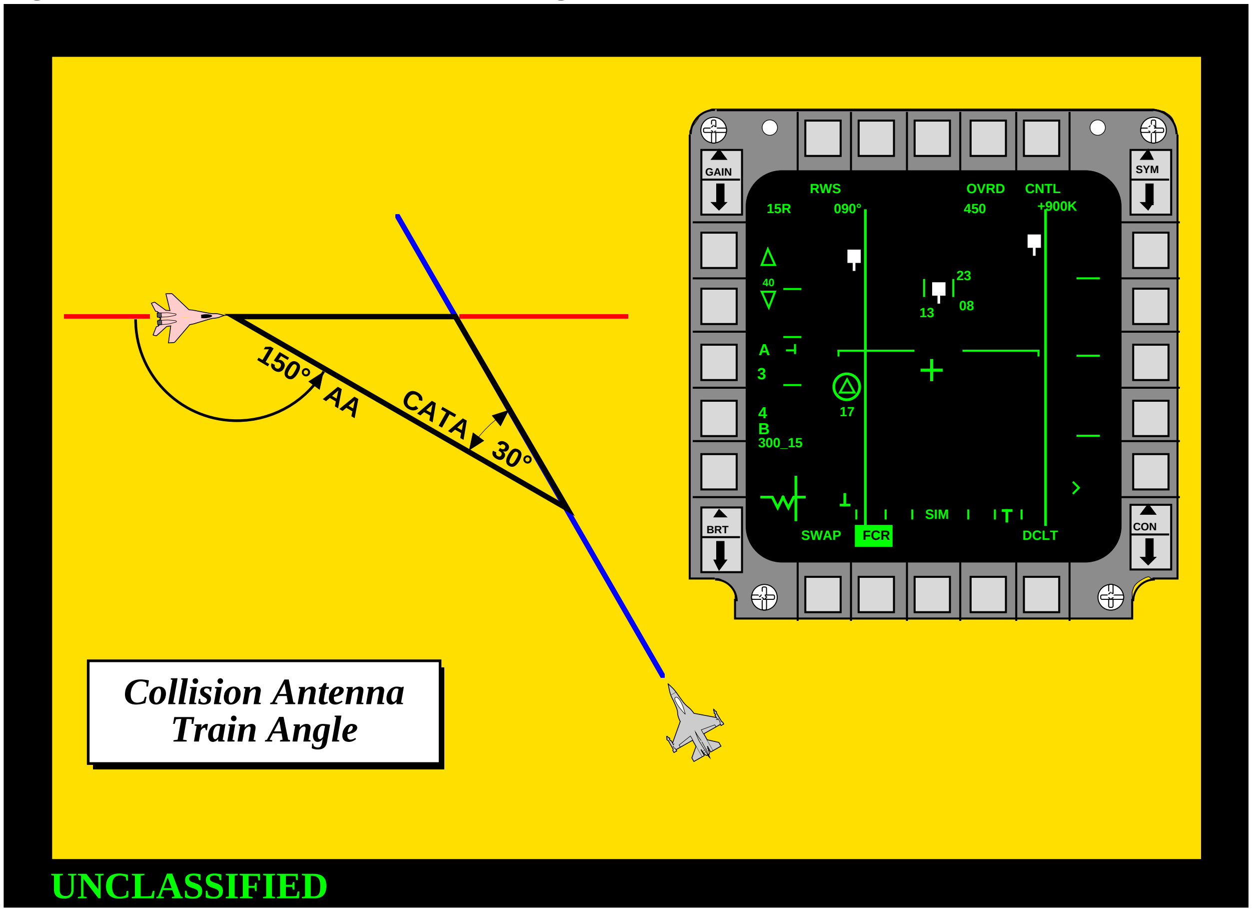


Figure 4.81. Collision Antenna Train Angle.



4.5.4.1. *Step 1*: CATA until 20 NM. The initial objective at long range is to close on the target. The easiest method of getting on the CATA requires the radar to track the target (single target track [STT], situational awareness mode [SAM], or track-while-scan [TWS]). Simply turn toward the intercept steering symbol, or steering cross, until it is centered at 0 degree azimuth. The target is on the CATA when the cross is centered. Some target aspects and speeds will not allow CATA steering without gimballing the contact—do not gimbal. The simplest approach for range to turn from CATA is to use 20 NM. Longer ranges are often used when target aspect is high (160 to 180 degrees) or when dictated by the tactical situation. Shorter ranges could be used when initial aspect is lower if the situation allows.

4.5.4.2. *Step 2*: Gain Altitude Separation and a Speed Advantage. Vertical offset, or vertical turning room, can actually be obtained as soon as you know target altitude. Normally, 4,000 to 6,000 feet is sufficient, weather/terrain permitting. A pure vertical stern conversion requires 8,000 to 10,000 feet from below or 5,000 to 7,000 feet from above. The following advantages of an altitude split may or may not apply to each situation:

4.5.4.2.1. Advantages:

- To get out of bandits radar coverage vertically.
- To use the ground clutter to help hide from the bandit's radar.

- To get the most favorable background to pick up the bandit visually.
- To get the most favorable background to hide your aircraft visually.
- To get an energy advantage.
- To hide in the bandit's blind areas.
- To reduce the horizontal turning room required; makes you less susceptible to a maneuvering target.

4.5.4.2.2. Disadvantages:

- Elevation control is more difficult at high look-up/look-down angles.
- If your radar breaks lock, it is harder to reacquire the target at closer ranges.
- It is easier to lose radar contact during a no-lock intercept.

4.5.4.2.3. Airspeed. A good rule of thumb for speed advantage is to have a 150 KCAS advantage if coming from below, and 50 to 100 KCAS advantage if coming from above. These rules of thumb are for medium altitude and may have to be adjusted for high altitude intercepts.

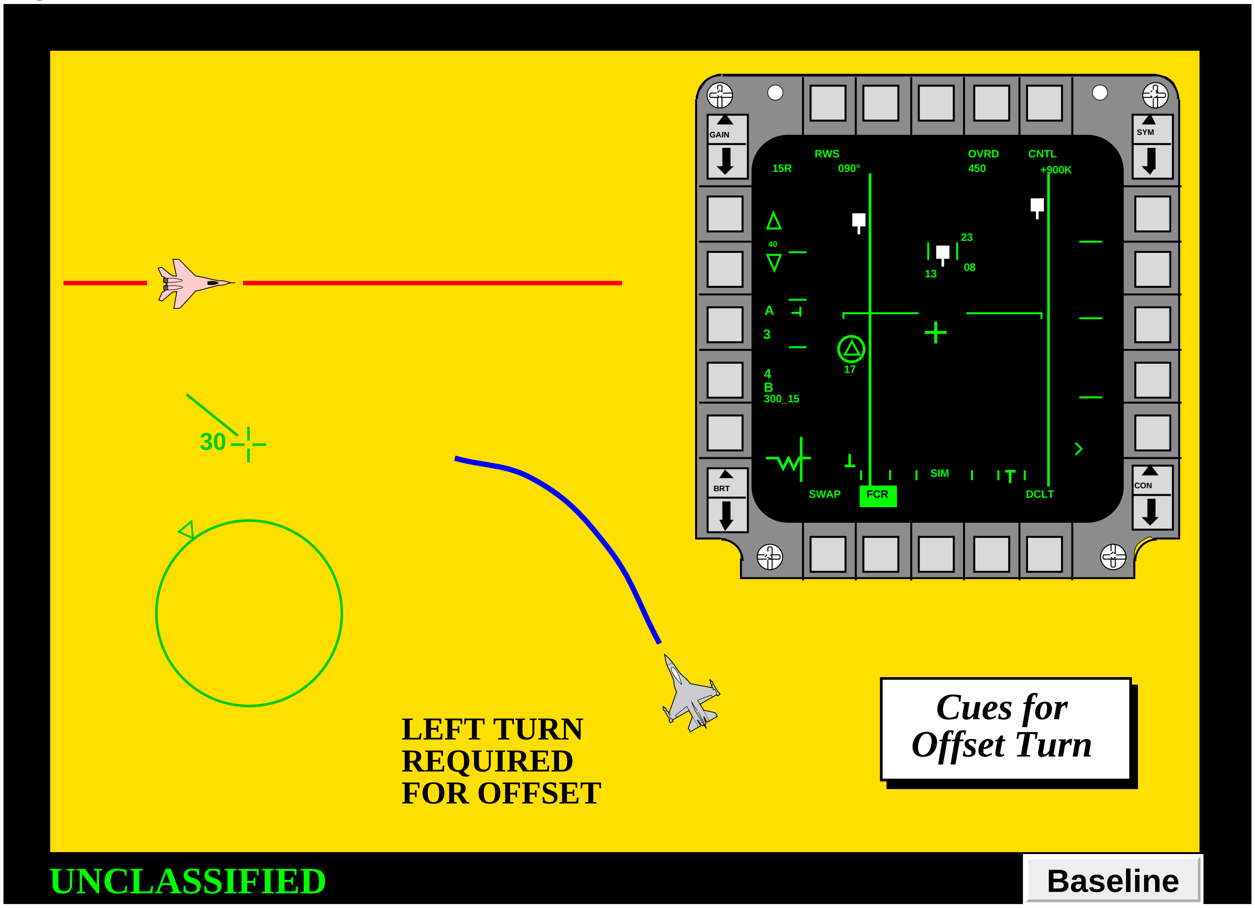
4.5.4.3. *Step 3*: Offset at 20 NM. Getting horizontal offset or horizontal turning room, requires analysis of the target AA. The AA is most easily read from the MFD, although the aspect symbol in the HUD is also useful. Remember the offset range may vary according to the situation but 20 NM should be the minimum used for a horizontal conversion from high aspect.

4.5.4.3.1. High Aspect. If AA is more than 120 degrees, turn to displace the target 10 to 50 degrees off the nose (10 to 50 degrees from the center of the MFD). The larger offset is used at higher aspects and the smaller offset is used at lower aspects. An additional technique is to limit total displacement (total of target and fighter ATA) to 60 degrees. Determine which way to turn and reference **Figure 4.82.,** Cues for Offset Turn:

- If aspect says "right" (e.g., 160R), turn to put target on the right side of the MFD.
- Assuming lead or pure pursuit was held prior to the turn: look at the aspect caret in the HUD. If it is right of center, turn right, and if it is left of center, turn left.
- Look at the aspect readout in the MFD. Turn opposite of the letter at the end of the aspect readout (e.g., if the aspect says "15R," turn "L" or left).

4.5.4.3.2. Holding Offset. Once offset is established, the target will drift further towards the edge of the MFD and bank into the target will be required to maintain the offset on the scope. The drift rate will increase as range and aspect decreases. During this phase, avoid gimballing the target off the scope (and losing contact) by reference to the HUD TLL. Never let the TLL exceed 50 degrees.

Figure 4.82. Cues for Offset Turn.



4.5.4.3.3. Beam Aspect. If initial AA is 120 degrees or less, remain as close to the CATA as possible without gimballing and proceed to subsequent steps of the baseline intercept.

4.5.4.3.4. *Step 4*: Monitor Aspect: Provided the target does not maneuver, AA will decrease continuously after the fighter has taken the correct horizontal offset. As the aspect approaches 120 degrees the offset may be reduced. If 120 degrees aspect is reached beyond approximately 10 NM, CATA is necessary to prevent the aspect from decreasing further. An increase in AA means the target is turning into the fighter. A rapid decrease in AA means that the target has turned away.

4.5.4.3.5. *Step 5*: Go Pure Pursuit: Once desired turning room has been achieved, pure pursuit should be established in anticipation of target visual. A stern conversion turn using pure pursuit from 120 degrees aspect and 6 to 8 NM can be conformably employed even during night and IMC intercepts. Other aspect and range combinations may be used in tactical situations to achieve other desired effects. No matter what the aspect, go pure pursuit no later than 5 NM. Pure pursuit takes extra advantage of F-16 avionics and small size. Use the HUD TLL to bring the target into the HUD FOV. During conversion from 120-degree aspect and 6 to 8 NM, at 3 to 4 NM range there should be approximately 90 degrees remaining to turn. The fighter may already have a tally and be in parameters for a missile shot. When a higher aspect merge is desired, the baseline 120 degrees aspect and 6 to 8 NM will be modified to use pure pursuit at higher aspects at longer ranges. Use BFM as required to maneuver into weapons parameters.

4.5.5. Wingman Responsibilities. The wingman's primary job during an intercept is to support lead to the merge. This includes checking six for the flight, targeting threats to lead's merge, engaging bandits not targeted by lead that are a factor, or calling lead off an engagement to deal with a higher threat. To perform these functions, the wingman must be able to do three things: (1) maintain formation, (2) communicate on the radio, and (3) employ valid weapons to kill.

4.5.5.1. Maintain Formation. A typical deployed formation for a tactical intercept is WID. During the offset phase the wingman should strive for WID. (See **paragraph 4.4.18.2**, WID.) If deployed to the inside of the turn, stacking high may cause loss of visual under the canopy rail during the conversion turn. A lower position solves this problem. If deployed to the outside, strive for the most forward position possible and maintain an energy advantage by stacking high. As lead converts on a non-maneuvering bandit, flying in the low/inside position requires caution to not be pushed out in front of lead's 3/9 line. On the other hand, the high/outside position requires anticipation to use altitude to accelerate and predict bandit lead to avoid being trapped at lead's 6 o'clock as the merge occurs.

4.5.5.2. Radio Communication. Efficient communications mean a rapid, meaningful exchange of information occurs to enhance everyone's SA on the problem at hand. When GCI talks to the flight, lead should answer. If all he can say is “VIPER ONE, CLEAN,” then at least GCI knows communication is good. When interflight communication occurs, both element members must say what they know or do not know. “VIPER ONE, CONTACT TWO GROUPS, 10 NM WEST BULLSEYE,” followed by silence is not communication. Viper Two must respond with “VIPER TWO, CLEAN/SAME” or whatever the pilot has. As the intercept progresses, any changes in what the element sees must be communicated and acknowledged. The ability to intercept what is on the radar is a prerequisite to communicating what you see. When lead talks or something changes in the radarscope, a radio call is required. Radio calls should be as complete as possible. “VIPER TWO, CONTACT” tells lead nothing about the contact's position, altitude, formation, maneuvering, or possible intentions. Often a wingman will only give part of the information available in an attempt to be brief. An incomplete radio call that begs a question will require extra radio calls.

4.5.5.3. Weapons Employment. Valid weapons employment is the only thing that will kill threats to the formation. A precise knowledge of the weapons envelopes, as well as the leader's criteria for engaging, will allow efficient weapon employment. For example, lead may brief the wingman to shoot any visually acquired target within 3 NM and 5,000 feet of altitude at the “HOSTILE” call. This rather restrictive criteria allows the wingman to engage threats within those parameters while maintaining formation integrity.

4.6. Gun Employment. The F-16 is one of the most lethal fighting machines in the world today. The combinations of missile technology and F-16 avionics make weapons employment in the tactical arena more effective. Missile employment is contained in AEM, Volume 5. The following discussion will center on gun employment.

4.6.1. Gunshot Range. Gunshots range from very controlled tracking opportunities to very dynamic snapshot situations. Apparent LOS relative to the shooter and the defender's turn rate capability dictate which type of shot is available; tactical considerations dictate which is the most feasible. Every gun opportunity must be judged and handled with proper concentration given the trade-off between target destruction and survival. How predictable can you be? How much energy can you expend and what will you do after the shot? Can you afford the time to take the shot?

4.6.2. Tactical Considerations. There are two basic situations where gun use is required: when the gun is the only available weapon, and when a target of opportunity (inside the missile minimum range/angle envelopes, but within gun parameters) presents itself. Gun solutions, especially in a dense air-threat environment, are fleeting in nature. You must see the situation approaching, react quickly to “fine tune” the gun solution, then kill or damage on the first attempt. But think twice about the time and energy dissipation required to generate such a situation if it does not already exist.

4.6.3. Attack the Cripples. Ideally, this would be an inexperienced pilot separated from his flight, low on fuel and energy, with no tally. Time to kill will be minimum in this situation. The bogey you would not choose to gun will be on the opposite end of the spectrum; he is experienced, has energy, fuel, and a tally, and his flight is with him. Minimize all solution errors which are controllable. There is one parameter which minimizes ***all*** errors associated with a dynamic air combat gun solution—range. Get in close to improve probability of kill (P_k).

4.6.4. Combat Gunshot Opportunities. Gunshot opportunities in combat are rare. Do not save rounds for other bandits, fire a lethal burst (generally 1 to 2 seconds) on the one you are engaged with, then immediately reposition to avoid the resulting fireball. Once separating, assume you have been targeted by a new threat (you have been very predictable and not checking six while getting your guns kill) and maneuver the aircraft accordingly.

4.6.5. Gunsights. Four different sighting references are available for use. The gun cross, the lead computing optical sight (LCOS), and the snapshot sight (SS) are available in many F-16s. The primary F-16 gunsight is the enhanced envelope gunsight (EEGS). Refer to TO 1F-16-34-1-1 for information on HUD symbology.

4.6.5.1. Gun Cross. The gun cross is always available and easily used—imagine the gun cross as being where the gun barrels are pointed. Proper aim is achieved by positioning the gun cross in the targets POM with the proper amount of lead. The gun cross is a very good reference to use to initially establish the aircraft in the target POM with some amount of lead. As range decreases, refine the lead angle by referencing the LCOS/EEGS pippers before firing. Without EEGS, the gun cross is the only usable reference during very dynamic, high AA shot attempts.

4.6.5.2. Lead Computing Optical Sight. The LCOS pipper represents a sighting reference with which the gun can be aimed. This pipper allows the pilot to establish the proper lead angle to kill the target. The key LCOS assumption is that the pilot is tracking the target with the pipper. In addition, target acceleration and shooter parameters (airspeed, G, range, and POM) remain constant during one TOF. If any of these parameters are changed during the bullet TOF, the pipper will be moving to the new "sight reference" and a solution settling time of one TOF is required.

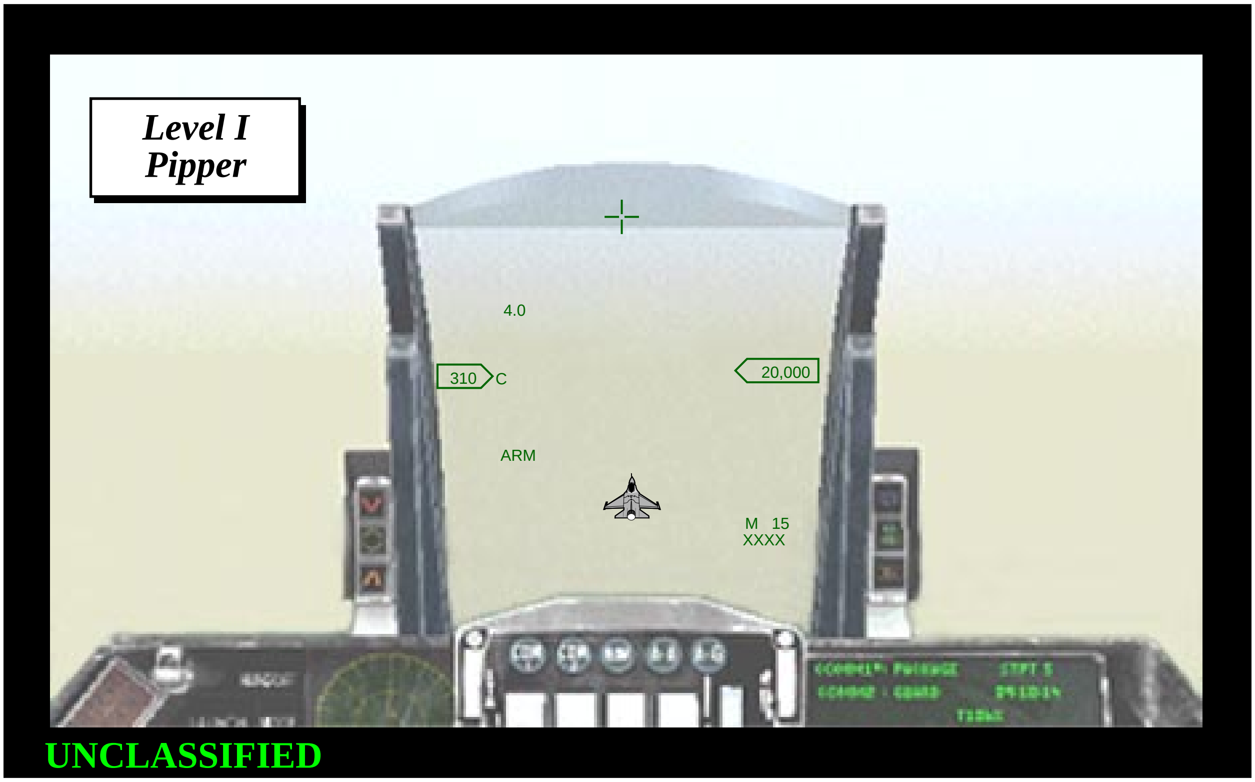
4.6.5.3. Snapshot. The snapshot display is a historic tracer gunsight. The principle of the system is to let you see where the bullets would be once they have left the gun. The snapshot algorithm functions completely independent of target parameters except range, which it uses to place the pipper on the continuously computed impact line (CCIL). The key is that the system is historic and not predictive in nature. It is very hard to use as an aiming reference and is not recommended because of the TOF lag in the presentation and the difficulty in managing the sight. However, it does provide an excellent shot evaluation capability. The accuracy of the sight is within 4 to 5 mils at 2,000 feet range as long as you have not been doing any rapid rolling maneuvers. LCOS and snapshot should always be called up together when employing the gun; use LCOS to aim with and snapshot to evaluate the shot.

4.6.5.4. EEGS. The EEGS sight is a combination LCOS and director gunsight. It provides the capability to accurately employ the gun at all aspects, with or without a radar lock, against either an evasive or predictable target, and out to maximum gun effective range. It is the primary sight in use in the F-16 today. The EEGS consists of five levels of displays, each providing an increasing level of capability depending upon system knowledge of fighter and target parameters (range, velocity, and acceleration). As the radar locks on to the target, the sight symbology smoothly transitions from Level II to Level V, without any large transient motions typical of LCOS mechanization.

4.6.5.4.1. EEGS Level I. The lowest level of symbology, Level I, consists of the gun cross and is used in the event of HUD or system failure. This symbol is the same as the current LCOS gun cross. (See **Figure 4.83.,** Level I Pipper.)

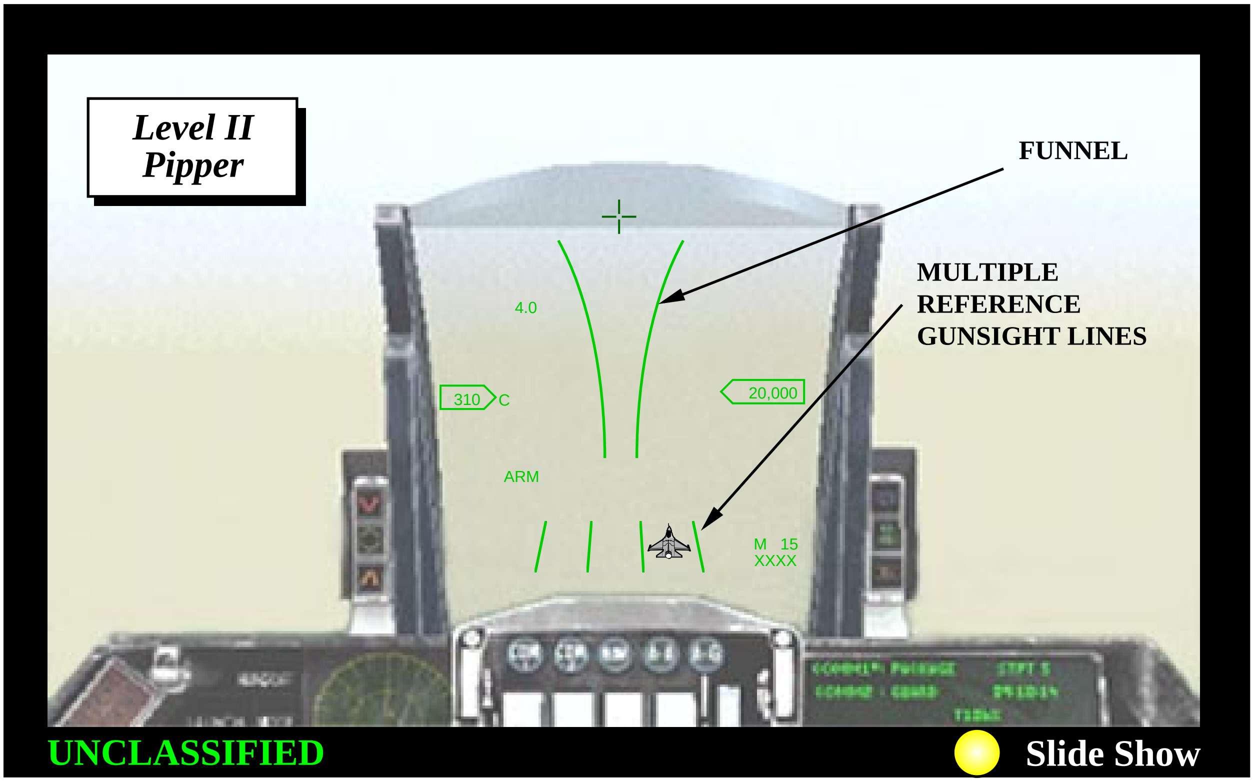
4.6.5.4.2. EEGS Level II. Level II is the basic no lock symbology. (See **Figure 4.84.,** Level II Pipper.) It consists of the funnel and the multiple reference gunsight (MRGS) lines. In Levels II and III, the dynamics of the funnel are based on a traditional LCOS system. Ranging can be obtained from wingspan matching. The funnel is used in low aspect (up to 50 degrees) or high aspect (130 to 180 degrees) shots to establish the aircraft in the proper POM and to track the target. The top of the funnel is 600 feet range and the bottom is between 2,500 and 3,000 feet, depending upon altitude. An accurate aiming solution exists when: (1) the target is being tracked at the point in the funnel where the wingspan is equal to the funnel width (assuming the proper wingspan is set in the DED); and (2) the shooter rate of turn approaches that of the LOS to the target. The only assumption here is that the target is turning into the attack. The pilot is thereby provided a sight with a good estimation of proper lead angle out to approximately 1,500 feet, where the width and slope of the funnel decreases to the point where wingspan matching is no longer accurate. The MRGS lines are used in high LOS rate attacks (such as beam aspect against a high-speed target) to establish yourself in the targets POM with excess lead. Finally, Level II symbology includes the firing evaluation display system (FEDS), simulated rounds which are fired at the rate of five per second while the trigger is depressed and are displayed on the HUD as dot pairs. The dot pairs move downward across the HUD in the same way that tracers would move had they been fired, and their width corresponds to their current range in mils (based on the data entry display [DED] entered wingspan).

Figure 4.83. Level I Pipper.



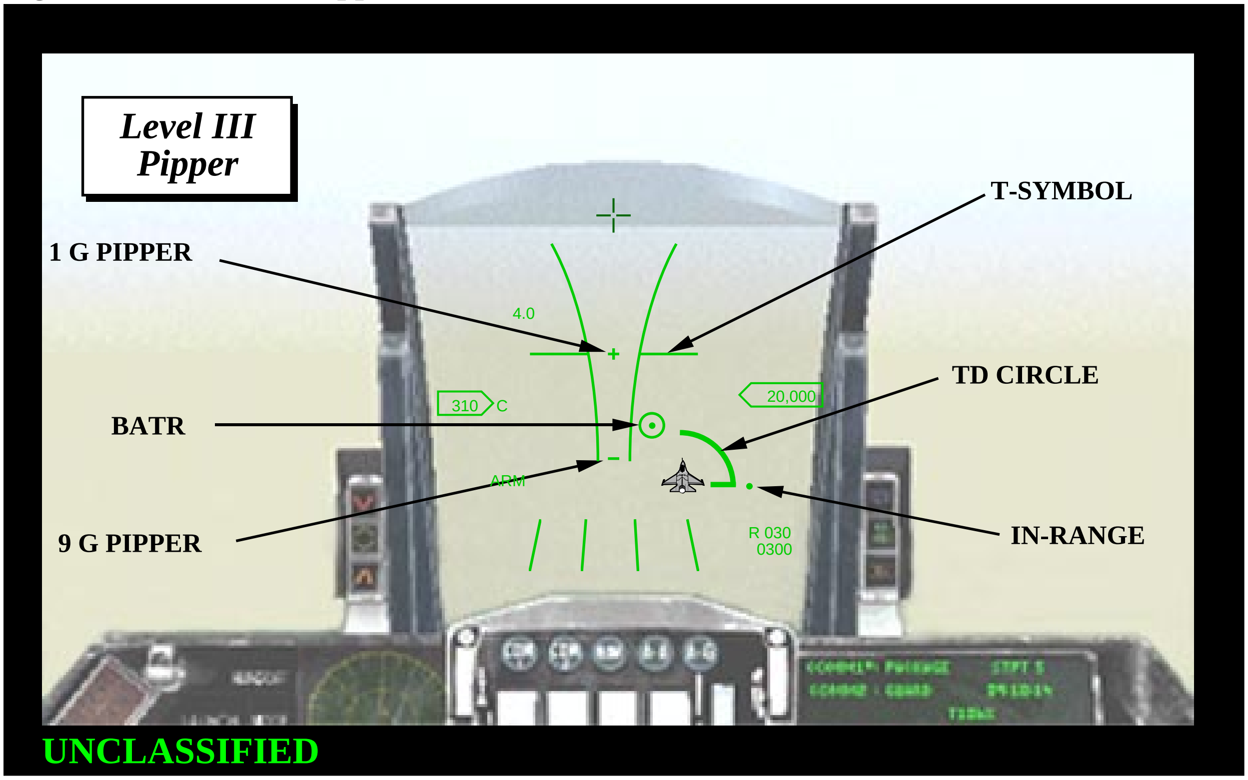
4.6.5.4.3. EEGS Level III. When radar lock-on occurs, target range is the first information available and is the only information needed for the system to smoothly transition to Level III. (See **Figure 4.85.**, Level III Pipper.) The funnel and MRGS lines are retained and function as in Level II. Four additional references are now also displayed: (1) a target designator (instead of the TD box) is centered on the target and displays a clock analog of target range; (2) a maximum range cue is displayed as a dot on the periphery. It shows the range which corresponds to a 1.5-second bullet TOF (this ensures the 800 feet per second bullet impact velocity needed for high explosive incendiary (HEI) fuze function); (3) three aiming references are displayed. The small cross is the 1 G pipper and indicates proper lead angle for a constant velocity (straight and level) target. The 9-G pipper is the in-plane maneuver potential line and shows proper lead angle for a target turning at maximum instantaneous rate. The algorithm assumes a maximum G of 7.3 (or 9.0—newer aircraft tapes) and a corner velocity of 350 KCAS in order to determine this value. This reference (the bar) gives the pilot a well-defined lead angle boundary to use as a reference in estimating the correct lead angle. Abeam the 1 G pipper are the out-of-plane maneuver potential lines which provide an aiming reference for an evasive target. The end of these lines indicates the potential movement by the target in 1 bullet TOF. Here the algorithm assumes a maximum sustained turn rate of 20 degrees per second at sea level. This turn rate decreases with increases in altitude and airspeed; (4) to assist in shot evaluation, a 6-mil circle (corresponding to the gun dispersion) is displayed after squeezing the trigger and showing the location of the bullets as they go through the target's range. This bullets at target range (BATR) symbol is used instead of the FEDS whenever valid target range is available and is displayed on the HUD from one TOF after opening fire to one TOF after releasing the trigger.

Figure 4.84. Level II Pipper.



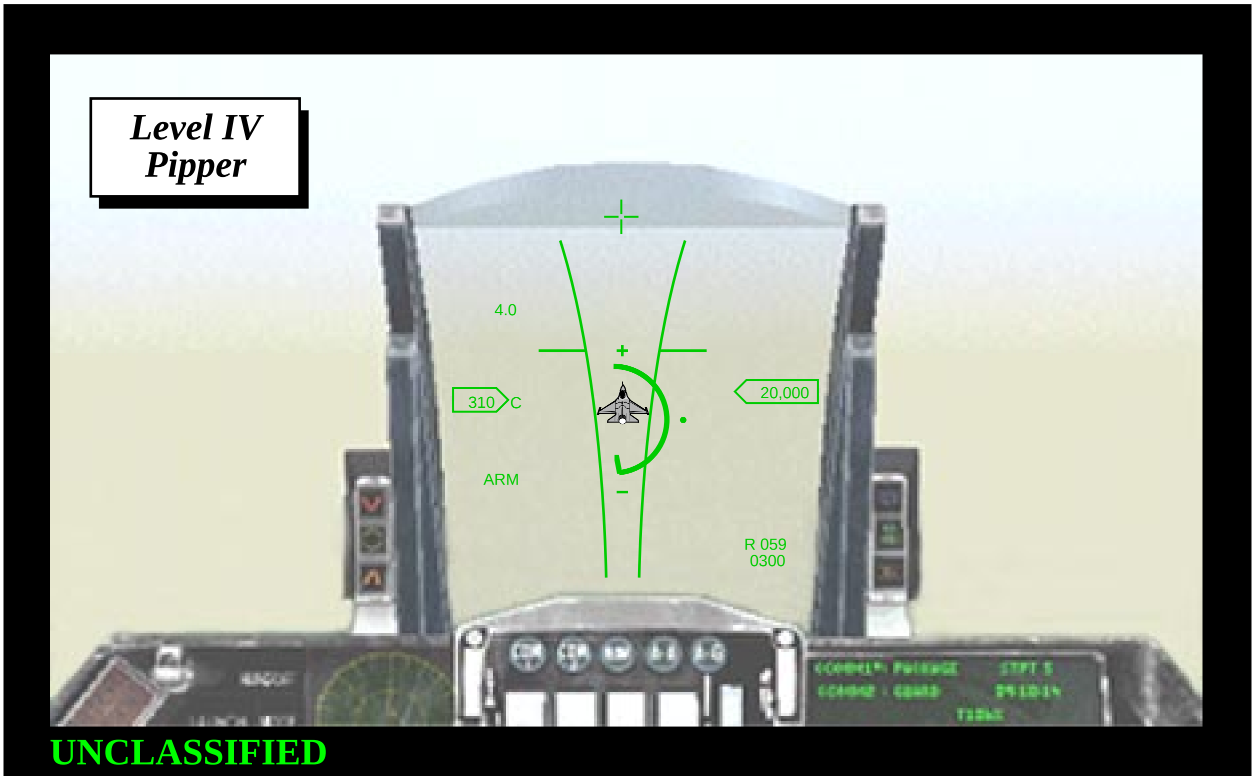
4.6.5.4.4. EEGS Level IV. Shortly after lock-on, the radar will obtain target velocity and the sight will advance to Level IV. (See **Figure 4.86.**, Level IV Pipper.) The sighting references now transition from a pure LCOS sight to a blended LCOS and director sight. A pure director sight is not feasible because at short ranges, radar-tracking errors cause the sight to jump around with a random, noisy motion, making it unusable. To smooth out the sight, the system behaves as an LCOS system inside 500 feet and a combination of LCOS and director systems outside 500 feet. The entire system, therefore, behaves as a mix of an LCOS solution within 500 feet and a director solution from 500 feet out. What this filtering means is the pilot must track the target for about 0.25 second before shooting, or shoot about 0.25 second before the pipper is on the target. The funnel retains its original shape but now responds to target maneuvers and is parallel to the target's POM. The MRGS lines are removed because the funnel now extends to the bottom of the HUD and can be used as an aiming reference at all target aspects. All remaining symbology is the same as in Level III.

Figure 4.85. Level III Pipper.



4.6.5.4.5. EEGS Level V. Several seconds after lock-on, the radar can determine target acceleration and the sight will transition to Level V. (See **Figure 4.87.**, Level V Pipper.) Once range is inside the computed maximum range, a 4-mil Level V pipper appears in the funnel. The Level V pipper uses the radar's estimate of target acceleration and the same LCOS/director blending as the funnel (LCOS lateral aiming error has been eliminated). The Level V pipper is a true "death dot" only in a stabilized solution (remember the 0.25 second settling time) against a target on a ***predictable flight path*** (constant POM, velocity, and G). The funnel and the other symbology remain and are the same as in Level IV.

Figure 4.86. Level IV Pipper.

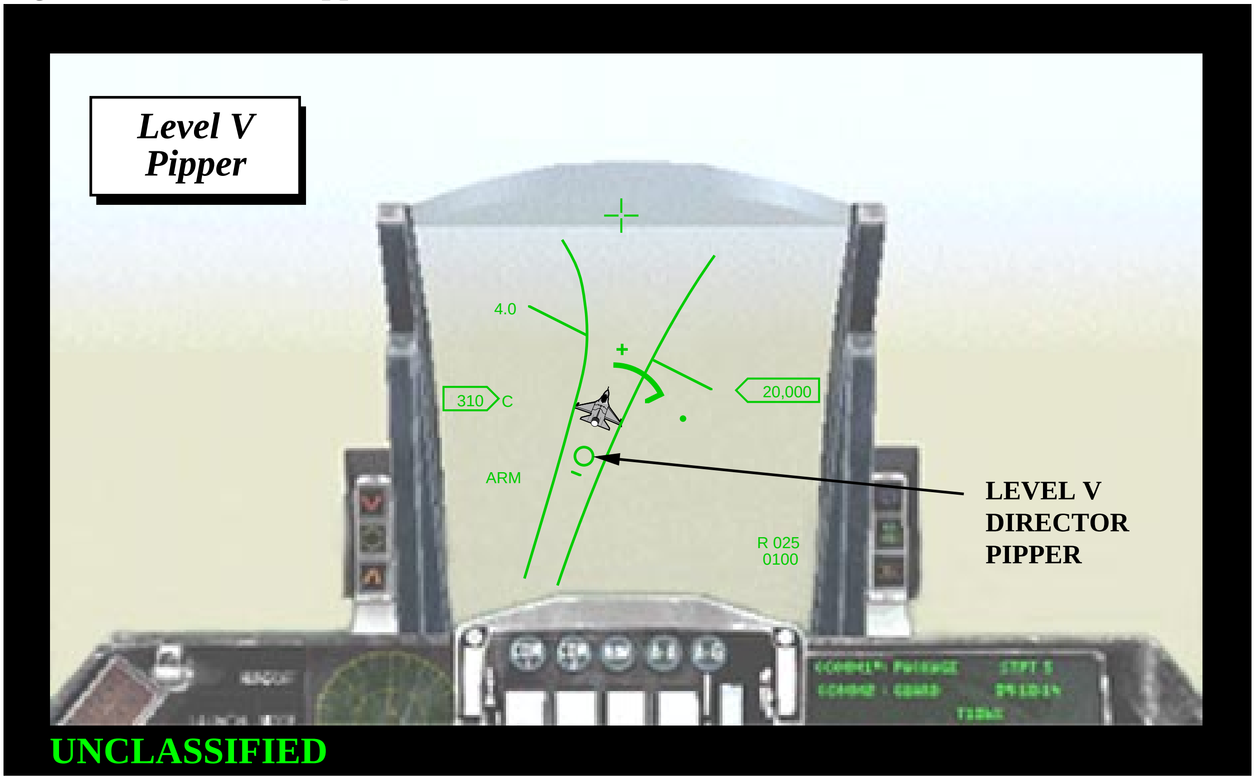


4.6.6. Employment Considerations. Gunnery errors can be separated into three categories, dispersion, systemic, and pilot-controlled errors.

4.6.6.1. Dispersion. Dispersion is different for each bullet and accounts for the shotgun type of pattern. The dispersion for our gun is 6 mils; meaning 80 percent of the bullets can be expected to hit inside of 6 mils.

4.6.6.2. System Errors. Systemic errors result from boresight inaccuracies, radar angle tracking inaccuracies, or any other nonpilot errors. These errors vary from day-to-day and from aircraft-to-aircraft and result in a movement of the burst center, some unknown distance from the aimpoint. In the F-16, the dominant systemic errors come from boresight and radar tracking errors. Boresight errors can be reduced to less than the 6-mil dispersion with a good boresight program. Radar tracking errors arise from the radar tracking different parts of the aircraft which induces errors in its estimate of velocity and acceleration. However, these errors typically lie along the targets flight path, producing a miss in front of or behind the target. Therefore, the best shooting technique to ensure at least some hits is to strafe the target along its flight path.

Figure 4.87. Level V Pipper.

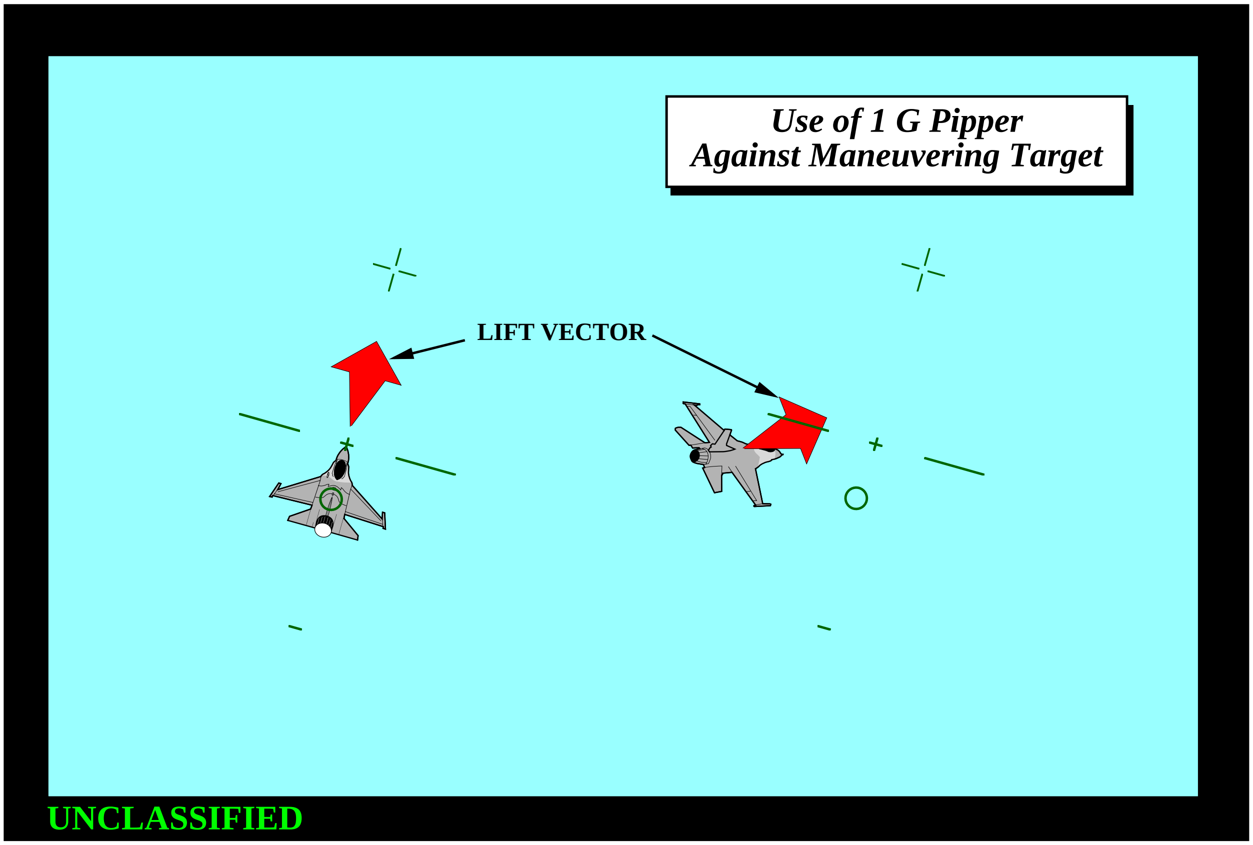


4.6.6.3. Pilot-Controlled Errors. The final type of errors concern pipper position relative to the target, the pilot-controlled errors. It is obvious that the pipper must be near the target to get a hit; however, systemic errors may cause a very precise track of the cockpit with the pipper to result in a very precise miss just forward of the nose. The bottom line regardless of which sighting system is used is that strafing the target along its flight path and firing a lethal burst will compensate for systemic errors and result in a higher probability of hitting and killing the target.

4.6.7. Enhanced Envelope Gunsight Employment Considerations. For low-aspect shots with a radar lock on, a simple technique is to use the 1 G pipper to track the target when outside maximum range. This will establish the POM and solve the majority of the lead angle requirements (remember from basic gun theory that of the total lead angle, about 85 percent is lead for target velocity and 15 percent for target acceleration). Using the 1 G pipper initially makes it easy to transition to either the in-plane or out-of-plane maneuver lines once in range. The pilot then opens fire and strafes the target along its Lv, using either the in-plane maneuver bar or the out-of-plane maneuver lines as a reference for the lead angle boundary.

4.6.7.1. Maneuvering Targets. By using the technique shown in **Figure 4.88.,** Use of 1 G Pipper Against Maneuvering Targets, the pilot is using the best qualities of each part of the system. The radar can get a quick, accurate measurement of target range and velocity but lags in its estimation of acceleration. The pilot is a poor estimator of target range and velocity, but can very quickly perceive a change in acceleration by watching the target's planform and motion. Therefore, by using range and velocity inputs from the radar and acceleration and POM from the pilot's perception, and then strafing the target over the area of uncertainty, the pilot can shoot and even hit targets.

Figure 4.88. Use of 1 G Pipper Against Maneuvering Targets.



4.6.7.2. Using the Director Pipper. With a full system lock and the Level V pipper displayed, the above technique is still valid. The 1 G pipper is less noisy than the Level V pipper and is much easier to track the target. Noise can be caused by ECM, chaff, large target size causing pinpoint track confusion, etc. Once in range, if the pilot sees the target remaining predictable, then transition to using the Level V pipper. Open fire about 0.25 second before the pipper is on the target and then increase G to strafe it from tail to nose (tail aspect).

4.6.7.3. No Lock Employment. Without a lock, the pilot must use funnel width in relation to the target's wingspan to determine the proper lead angle. An accurate firing burst can be obtained by first centering the target in the funnel. Next, open fire with the wingspan slightly larger or smaller than the funnel, let the target slowly track up or down the funnel, and cease-fire when the wingspan is equal to the width of the funnel. It is important to remember that whenever relative motion exists between the funnel and the target, the gun is properly aimed before the target wingspan reaches the width of the funnel due to the LCOS filtering properties.

4.6.7.4. Beam Aspect Employment. The dynamics of beam shots require large lead angles and are difficult because the required turn rate to track the target exceeds the aircraft's turn capability at short ranges. In the 1v1 engagement, a beam shot could result in an exchange of 3/9 line if the shot is missed. However, in a multi-bogey environment, it may not be sound to slow down and anchor in an attempt to achieve a low-aspect shot. Against a bomber with a tail gun, a beam/front aspect shot is the best option. A beam aspect shot requires that the pilot establish the aircraft in plane with excess lead angle early on. In Level II and III, the MRGS lines are used initially to accomplish this by tracking the target on or between any of the MRGS lines. This puts the gun in lead and eliminates lateral error as you close. In Level IV and V, the funnel extends to the bottom of the HUD and is easily used to accomplish this initial lead requirement. This lead angle is maintained until range has decreased to the point where G forces are as high as the pilot is willing to accept or until lateral control is too difficult. Aircraft G is then held constant as the gun is fired and the target moves up in the HUD. In this way, bullets are passing from in front of the target to behind it. Controlling lateral error (keeping the target centered in the funnel) becomes the critical factor, not lead angle.

4.6.7.5. High-Aspect Employment. High-aspect shots are very fleeting in nature and are currently restricted above 135 degrees AA. However, in a multi-bogey environment, a high aspect shot and a separation may be the best alternative if unable to get a missile shot and are merging at high aspect. Employing the gun in a high aspect attack first requires that the pilot recognize the opportunity for such a shot early on. A pursuit course with the target near the top of the funnel should be initiated so that the shot does not take place with too small a HCA for a separation during the disengagement. As the pilot approaches maximum range (about 5,000 feet at 120 degrees), establish the required lead and open fire. Open fire with the pipper (either Level V pipper or 1 G pipper) coming up from behind the target, pull the pipper through the target, then relax Gs to let the target now track back through the pipper. This will create a burst pattern from behind to forward to behind the target. This technique will compensate for any lead angle errors and again make lateral control the critical task. Without a radar lock, the pilot must now analyze range to determine when to open fire. Keeping the target near the lower third of the funnel until the wingspan approaches the size of the bottom of the funnel (approximately 3,000 feet) can approximate this. Now open fire and track the target until the wingspan is larger than the funnel, then relax the G and let the target track up the funnel to ensure sufficient separation.

4.6.8. Lead Computing Optical Sight Considerations. In LCOS, pipper drift indicates miss vector. This can occur if the pipper is moving in the HUD or if the pipper (stationary in the HUD) is moving in relation to the target. The lag line in LCOS-only mode is an indication of this movement. A pipper that is drifting across the target is an indication the target will be missed in the direction of the drift, even if you open fire with the pipper on the target. Pipper drift is a good indication of the miss vector in both direction and magnitude. Settling of the sight is very rapid initially and then slows as it nears the solution. Beyond 2,000 feet, LCOS settling time greatly increases, making a stabilized solution more difficult to achieve.

4.6.8.1. Aiming Errors. With a full system lock, the LCOS algorithm produces a lateral aiming error at beam aspects. The primary factors in the algorithm-induced error are AA and bullet TOF. Firing at low aspect or from short ranges can reduce this error. As shown in **Figure 4.88.,** Use of 1 G Pipper Against Maneuvering Targets, even at 90 degrees aspect, a 0.5 second TOF shot (approximately 1,000 feet) produces only a 3 feet mil (3 feet) miss, well within tolerance. The same shot, however, at a 1 second TOF (approximately 2,000 feet) is a 7 mil (14 feet) miss which could be significant.

4.6.8.1.1. Radar Lock. During radar lock transitions, the LCOS pipper jumps to the gun cross while the target state estimator settles. At short ranges, an ACM lock just prior to shooting may cause enough distraction to miss the shot opportunity. A false lock will also cause the pipper to be improperly placed. One technique is to have NAM/RWS selected in DGFT to preclude short-range radar lock and to avoid these undesirable effects.

4.6.8.1.2. No Lock. Without a lock, the system assumes that target G and velocity are equal to shooter G and velocity, that aspect is 0 degree, and that range to the target is either 700 feet or 1,500 feet to predict the required lead angle. The aspect and G assumptions produce an overlead situation that is minimized at low aspect and short ranges. The range error caused by the assumption of the preset range can be either overlead or underlead. However, the 1,500 feet option should be initially set in because it offers more flexibility throughout the entire envelope of typical gunshots.

4.6.8.2. LCOS Employment. The proper technique when aiming with the LCOS pipper is to establish the aircraft in the POM early, open fire one bullet TOF prior to the pipper being on the target, then let the pipper drift slowly through the target and cease fire when it reaches the other end.

4.6.8.2.1. Shoot with dual mode LCOS and snapshot. Try to learn to use the LCOS while assessing the snapshot pipper simultaneously.

4.6.8.2.2. Out-of-plane snapshots require the use of the gun cross, ***not*** the LCOS pipper as the primary aiming reference.

4.6.8.2.3. Put the gun cross in front of the target’s POM, and then fly it halfway through the target’s top wing.

4.6.8.2.4. Squeeze the trigger when the target is outside 30 degrees of your nose/gun cross to allow for enough lead.

4.6.8.2.5. The more lead you pull, the faster you will close with the target (watch the training rules).

4.6.8.2.6. Never lose sight of the target. If you have to pull the target below the nose to establish lead, you either waited too long or the target has too much energy to gun.

4.6.9. Summary. The gun is an effective, short-range, all-aspect weapon if properly used. Target aspect and geometry are prime players—be mentally aware of what you want to see in terms of gunshot opportunities and take advantage of them as they arise or when you make them happen. Know the logic and inherent errors of gunsight and where to put it for maximum effectiveness. Effective gun employment requires practice and, most of all, mental preparation. The gun must be in the target's POM, gun cross in lead, and in range. Instead of trying to fly the pipper to the target, concentrate on establishing the gun cross in front of the target and in the target's POM. Then, using the LCOS/EEGS pipper as an indicator of the proper lead angle, make small plane and lead angle changes to superimpose the pipper on the target. Open fire before the pipper reaches the target, and then strafe the target from one end to the other. If variables change, reposition and press again if the threat allows:

4.6.9.1. Watch the target and not the sight. Learn to anticipate sight and target coincidence and open fire one TOF before.

4.6.9.2. Do not wish the pipper onto the target. Discipline yourself to fly it to a precise point, open fire, then let it slowly drift through the target.

4.6.9.3. Anticipate a target reaction. If the defender maneuvers out-of-plane, accept a snapshot and separate or reposition for another attempt.

4.6.9.4. Fire at close range, commensurate with safety and training rules. The shorter the bullet TOF, the more accurate the pipper placement is, and the less reaction time the target has to defeat the shot.

4.6.9.5. At cease-fire, have a plan—be ready to reposition or separate if the bandit does not blow up.

CHAPTER 5

AIR-TO-SURFACE

5.1. Air-to-Surface Mission. Surface attack is the "bread and butter" mission of the F-16. Given current surface-to-air and air-to-air threat capabilities, "hauling iron" is a challenging mission that requires a complete knowledge of the aircraft systems, handling characteristics, and ordnance. This chapter presents discussions on pre-mission planning, delivery parameters, surface attack checks, low- and medium-altitude considerations, visual and non-visual bombing, controlled range patterns, and pop-up deliveries. Advanced Employment Manual 3-1, Volume 5, Dash 34 series, and appropriate regulations should be consulted to further supplement this manual.

5.2. Preparation.

5.2.1. Air-to-Surface Specifics. Contact the flight lead the day prior to the mission and allow sufficient mission planning time prior to brief time. The game plan and subsequent execution is a direct reflection of the effort put into mission planning. Considerations include, but are not limited to:

- Target and desired objectives.
- Threats (surface, air, en route, and terminal).
- Aircraft configuration and ordnance load.

5.2.2. Air-to-Surface Planning and Products. With this information, the planning phase can begin. It is important that everyone in the flight participates in the mission planning. Expect duties to be delegated to each member of the flight. Data required and produced include the following:

5.2.2.1. Weather. Note winds, ceilings, visibilities, and sun angles for the target area and route. Obtain Tactical Decision Aid (TDA) for electro-optical (EO) weapon planning and employment.

5.2.2.2. Takeoff and landing data reflecting the actual aircraft configuration.

5.2.2.3. Review aircraft bomb footprint logs to determine if there are any trends that would effect bombing accuracy.

5.2.2.4. Weapons data (carriage, employment, and jettison).

5.2.2.5. Route and target maps.

5.2.2.6. Attack parameters.

5.3. Air-to-Ground Mission Planning.

5.3.1. Planning Factors. Several factors must be considered when planning air-to-ground weapons employment. First, a thorough threat analysis must be accomplished to determine attack axis and survivability by minimizing exposure. Second, target and munitions compatibility must be determined. For example, dropping cluster bomb unit (CBU) to destroy a concrete bridge will not provide the required munition effects. Third, the delivery must achieve the desired weapons effect. If a 60-degree impact angle is required, it is easy to see that a 10-degree low-angle low-drag (LALD) delivery will not suffice. Refer to Allied Conventional Employment (ACE) planning programs for further weapons effects considerations.

5.3.2. Delivery Parameters. Air-to-surface attacks must allow for both safe delivery specifics and effective weapons effects. Release altitude is based on trade-offs between weapons arming, threat avoidance, system accuracy, terrain avoidance, and safe escape from weapon fragmentation. Additional training restrictions and regulations may also impact attack planning. Refer to Dash 34 series manuals and Computed Weapons Delivery Software (CWDS) for an in-depth discussion on these topics. In addition, the Dash 34 will describe the available escape maneuvers: level straight through, climbing, turning safe escape maneuvers, turning maneuver level turn, and backup safe escape maneuvers.

5.3.3. Fuze Arm Categories and F-16 Avionics.

5.3.3.1. Arming Delay (CAT 1). For CAT 1 (impact fuze) weapons, the value of the arming delay (AD) entered into the stores management system (SMS) should be IAW the following formula:

F-16A: AD + fuze arm tolerance + any inherent delays = SMS AD time

For example, using a fuze arm time of 4.0 seconds plus 20 percent (0.8) tolerance, the AD entered in the SMS would be 4.8 seconds. If the fire control computer (FCC) computes a bomb TOF less than 4.8 seconds, the pull-up anticipation cue (PUAC) resets to provide ground clobber information and “LOW” flashes next to the flight path marker (FPM). (See **Figure 5.1.**, Fuze Arm Warning.)

5.3.3.2. Arming Delay (CAT 2). For CAT 2 (proximity fuzed) weapons, AD and burst altitude (BA) values are used to provide the FCC with information as to where the weapon ballistics will change. The FCC assumes the weapons will fall in a certain trajectory until the BA conditions are met and the fuze functions to change the ballistics. For CAT 2 weapons, the BA determines where the pipper is displayed while the AD determines PUAC cue information. Therefore, the BA in the SMS must be the same as the value set on the weapon fuze to ensure an accurate pipper.

5.3.3.3. Arming delay (CAT 3). For CAT 3 (timer) weapons, the AD positions the pipper in the HUD. This is due to the fact that the weapons will function at the expiration of the arming time versus a proximity fuze function as in a CAT 2 weapon. The BA with this type of weapon now drives the PUAC cue display. (See **Figure 5.2.**, Fuze Categories.)

Figure 5.1. Fuze Arm Warning.

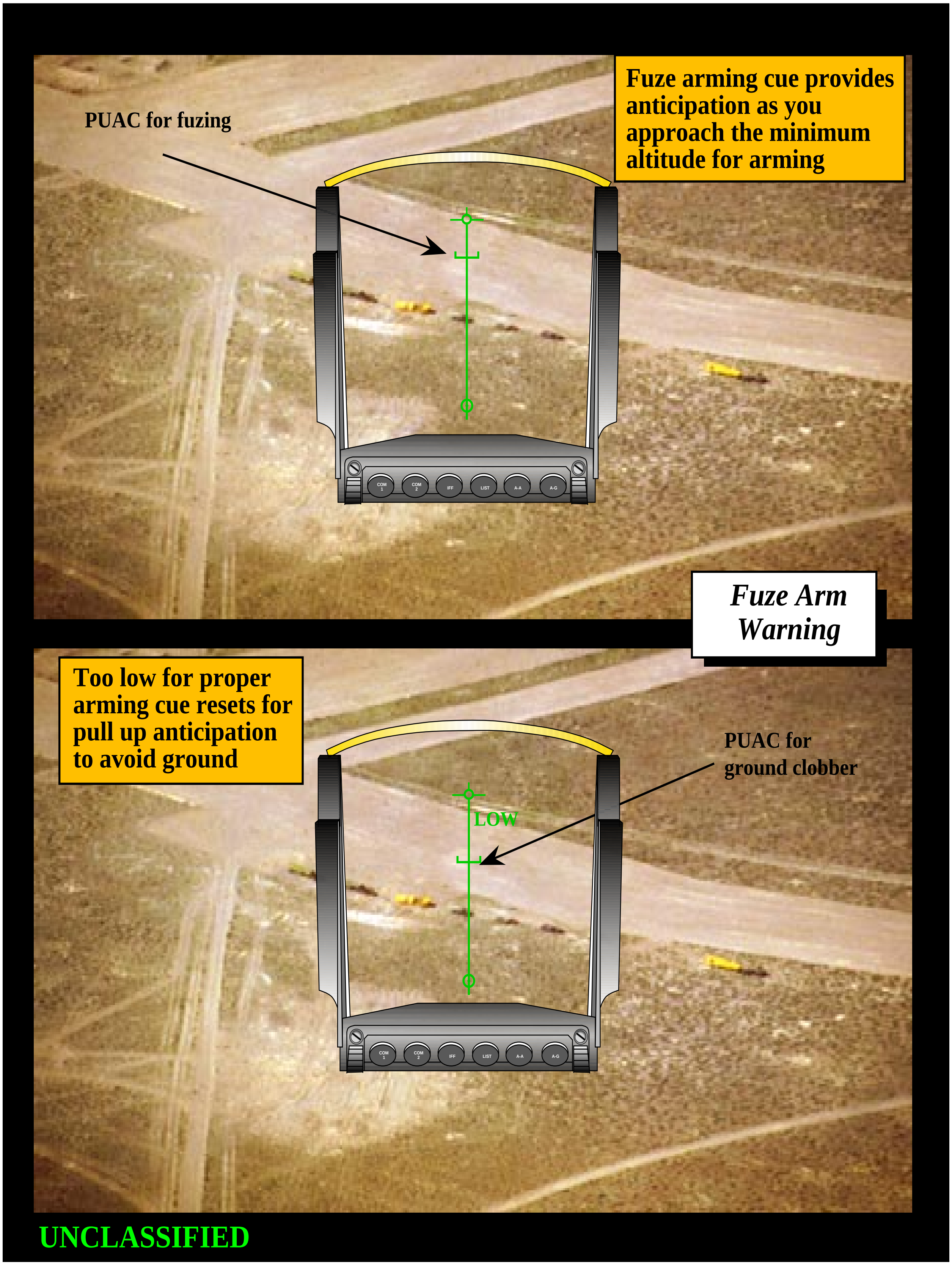
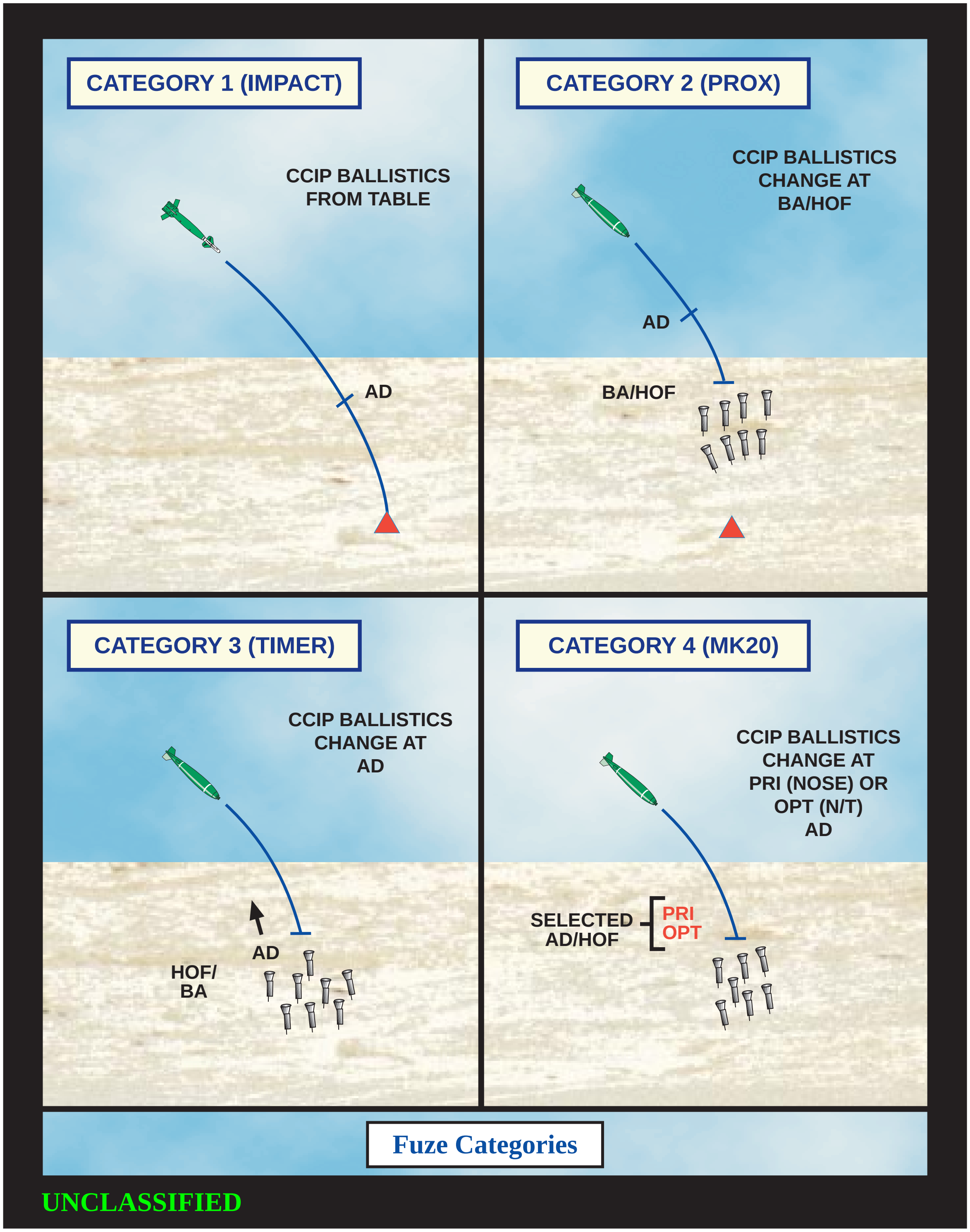


Figure 5.2. Fuze Categories.



5.3.4. Safe Escape and F-16 Avionics. The F-16 head-up display (HUD) and radar displays will provide an indication of when a recovery is required to avoid ground impact. Load an AD/ BA in the SMS to provide a HUD display ("LOW") when release parameters result in bomb TOF less than that required for fuze arm/function. The FCC ***does not*** compute a minimum altitude for safe escape. This is the pilot's responsibility and can be done only by reference to the safe escape tables in CWDS and the Dash 34. For example, if an AD of 4.4 seconds is loaded into the SMS and a level delivery (straight and level escape maneuver) was performed at 500 KTAS and 500 feet AGL; the delivery would be below minimum frag clearance (Safe Escape) criteria. There are no HUD warnings, and the fuze would have sufficient time to arm prior to impact. It is the pilot's responsibility to ensure minimum release altitudes (MRA) are not exceeded and valid safe escape maneuvers are always accomplished.

5.4. Surface Attack Checks.

5.4.1. Preflight. Allow extra time for ordnance preflight. If you find a problem, you will need time to have the weapons shop correct the problem and still start on time. Since munitions problems are not uncommon, do your weapons preflight as soon as you arrive at the aircraft. Contact the weapons supervisor immediately and inform your flight lead of any problems.

5.4.1.1. Be sure the load matches the planned configuration.

5.4.1.2. Use the Dash 34 checklist to preflight ordnance.

5.4.1.3. If a hot gun is required, ensure the gun electrical safety pin is installed outside the purge door, the safety tool/wire is removed, rounds counter set, and rounds limiter switch—on.

5.4.1.4. Note canopy coefficients prior to start.

5.4.2. After Start Checks.

5.4.2.1. INS “Swing” Check. When the inertial navigation system (INS) alignment is complete, it is a good technique to run through all the programmed destinations and compare bearing and distance from present positions with pre-computed values on your card.

5.4.2.2. Ground Speed (GS) Check. GS on the INS should read zero after alignment. Any GS reading other than zero when you are still in the chocks indicates errors in the horizontal accelerometers. These errors will result in navigation and bombing errors. If GS reads greater than zero immediately after alignment, consider doing another alignment.

5.4.2.3. Vertical Velocity Indicator (VVI) Check. Note the position of the VVI in the HUD or VVI gauge. Any reading other than zero indicates a bad vertical accelerometer which will result in erratic 12 and 6 o'clock errors.

5.4.2.4. Camera Check. In order to verify proper camera coefficients, a ground stabilized camera check is recommended on every sortie in which videotape recorder (VTR) assessment is used. Turn the VTR to HUD, switch on, turn the Master Arm switch to SIMULATE, and select A/G Master mode with dive toss (DTOS) symbology displayed. Also, display the HUD and camera coefficients in the data entry display (DED). Move the DTOS box to the lower portion of the HUD, approximately 5 to 10 degrees nose low, where planned release conditions will occur. An airborne check should also be accomplished. This provides a more accurate assessment of the camera alignment due to the increase in slant range to the reference point. Postflight review of this check will enable the pilot to determine mil displacement if the camera coefficients are in error. Camera coefficients should only be changed from airborne camera checks.

5.4.3. End of Runway Check. After stopping at end of runway (EOR), confirm all weapons switches safe and keep hands in full view during arming. Remember that aircraft should not taxi in front of aircraft with forward firing ordnance being armed or de-armed.

5.4.3.1. Verify correct SMS loading and inventory. If simulated deliveries or A/S weapons check will be accomplished, select an uncarted station and load zero quantity weapons there.

5.4.3.2. As soon as you stop in the arming area, check your GS and HUD VVI. If GS is excessive (equal to or greater than 3 knots), consider accomplishing another alignment.

5.4.3.3. RLG-equipped aircraft can perform an enhanced interrupted alignment (EIA) if desired.

5.4.4. Airborne Ordnance Check. The bomb check or battle damage check is normally done shortly after takeoff and when leaving the range. It is done only in daytime and is a visual confirmation of bomb condition and expenditure. The checking pilot visually inspects each aircraft for hung ordnance, “spinners” (activated fuzes), and battle damage. After completing the inspection, the pilot returns to the original position and is inspected by another pilot in the flight. A battle damage check should also be done on every sortie when clear of the target area and outside the threat area.

5.4.5. Airborne Computed Checks.

5.4.5.1. Air-to-Air System Check. While performing an air-to-air system check, the pilot should note the position of the target aircraft in the target designator (TD) box. A target not appearing in the TD box could indicate either a bad radar boresight or a bad HUD boresight.

5.4.5.2. Air-to-Ground System Check. After takeoff, during the descent to a low level, or while entering a range, the pilot should check all A/G modes. With the Master Arm switch in SIMULATE and with an uncarted station selected, select continuously computed impact point (CCIP) and observe the pipper while flying over relatively smooth terrain. The pipper should track smoothly and valid air-to-ground ranging (AGR) should be displayed in the HUD. If not, the radar is not providing consistent data for the weapons solution. The fire control radar (FCR) should indicate a valid lock-on to the ground by displaying a diamond symbol on the REO. Slant range should be displayed in the HUD and remain relatively constant. At medium altitude, a roll in can be accomplished to determine the quality of the AGR track. Check DTOS and verify TD box will ground stabilize. Set the ground map (GM) display and verify desired gains and REO tuning while in CCRP.

5.4.5.3. Altitude Calibration (ACAL). Anytime you suspect errors in system altitude, an ACAL should be performed before bombing. Avoid using the FCR for an ACAL if you have known AGR radar problems.

5.4.5.4. G-tolerance, Loss of Consciousness (G-LOC), and Preparation. A dedicated G-awareness exercise should be conducted IAW **Chapter 9** on all missions when required.

5.5. Ingress and Egress.

5.5.1. FENCE Check. Certain items should be checked to ensure that switches and avionics are set up properly prior to entering a hostile area. This may be just beyond the field boundary, so it may be necessary to do some of these checks prior to takeoff. Others may be delayed until just prior to the push out of the orbit, mission dependent.

5.5.1.1. One way to ensure a thorough check is made of your combat capabilities and are ready to fight, is by using the word FENCE as an acronym. An example of the minimum items to be checked are shown in **Table 5.1.**, FENCE Check. These items can be accomplished in any order.

Table 5.1. FENCE Check.

FENCE	Check
F Fuel	Check balance, total, NORM feed and tank inerting selected. ***NOTE:*** Tank inerting may cause slow external fuel transfer.
E Emitters	Use the acronym TRAIL.
T TACAN	Check operation. A/A set as briefed.
R Radar	Set CCR and altitude coverage as briefed.
A ALQ and ALR	Set proper ECM technique and RWR as required.
I IFF	Set modes, codes as required.
L Lights	All exterior off.
N Navigation	INS check/verify steerpoints. Confirm GPS/Nav status High/High . Accomplish update (FIX/ACAL) if necessary on preplanned point.
C Chaff and Flares	Check programmer prior to strapping in. ARM and check operation airborne.
E Employment	Recheck SMS programming to include DGFT, MSL OVRRD, AIM-120 BIT and identification set as briefed, AIM-9 cooling/tones, and rail priority. Check arming options to include weapon, fuze arming option, release pulses, spacing, and delivery modes. Ensure Master Arm is set as required, HUD has correct symbology, proper arm indication, and SOI/SOR in proper place. Confirm TGP laser code is set IAW mission requirements and Arm is required. Turn up volumes on missile, RWR, UHF, VHF, and secure voice to desired levels.
UNCLASSIFIED	

5.5.1.2. A complex mission will also have a complex FENCE check. Omission of even a single item could result in a dry pass, a missed shot opportunity, or even risk being shot down due to unarmed flares or electronic countermeasure (ECM) systems. It may be helpful to write down critical FENCE check items on your mission card.

5.5.2. Low-Altitude Considerations. The use of the low-altitude structure is one method of target area ingress and egress. How low to fly and the time spent there is determined by weather, weapons effect considerations, and threat capabilities. Selective use of the low-altitude structure is an effective method of getting to and from target areas, when thoroughly planned and executed. Do not fly lower than the altitude where you can safely and effectively perform all assigned tasks. A thorough knowledge of threat capabilities and weapon effects is essential when selecting low altitude as a game plan. Refer to **Chapter 7** for low-altitude navigation operations.

5.5.2.1. Altitude Selection. Depending on the threat scenario, fly at an altitude that safely balances detection, threat avoidance, and cockpit operations. This regime allows the flight to avoid the ground, navigate, and conduct visual look out. Maneuvering tactical formations at low altitude is a difficult task requiring a high degree of skill and proficiency. Checking six, monitoring the radar, and interpreting defensive systems are difficult and become degraded when compared to these activities at higher altitudes. The advantages of operating at low altitude must be weighed against the inherent disadvantages when deciding to maneuver in this regime.

5.5.2.2. Low-Altitude Advantages:

5.5.2.2.1. Detection by threats may be delayed.

5.5.2.2.2. Exposure time to surface-to-air threats is reduced. Threat systems are restricted to line of sight (LOS). Terrain degrades the detection and tracking capabilities of many systems.

5.5.2.2.3. Many air-to-air threats have little or no radar and missile capability at low and very low altitudes. Look-down/shoot-down fighters provide a low-altitude capability, but all weapons systems have reduced effectiveness at low altitude.

5.5.2.2.4. Below the weather operations are possible if the threat allows.

5.5.2.3. Low-Altitude Disadvantages:

5.5.2.3.1. Proximity to the ground is the most significant disadvantage. The demand on your flying skills is greater than at higher altitudes.

5.5.2.3.2. Navigation can be more difficult. You see much less of the “big picture” and can quickly become disoriented regarding your position, or confused by intentional alterations of the target area. Task saturation, due to low-altitude operations, degrades time available to concentrate on position analysis.

5.5.2.3.3. Fuel flow for a specific true airspeed is significantly higher at low altitude, resulting in a smaller combat radius. Missions requiring extended periods of low-altitude operations require thorough mission planning to ensure sufficient fuel is available. Continuation fuels must be calculated for significant mission events (FEBA crossing, at the IP, and in the target area) to aid in decision making. Jettison and abort decisions should be determined before flight.

5.5.2.3.4. Low-altitude operations put you in the center of antiaircraft artillery (AAA) engagement zones.

5.5.3. Medium-Altitude Considerations. Flying at medium altitude is another viable option for target area ingress and egress in certain circumstances. The same planning process must occur when selecting the altitude flown. Threat avoidance, early warning detection, and aircraft performance are but a few considerations.

5.5.3.1. Navigation. The same techniques for dead reckoning (DR) and map reading at low altitude apply at medium altitude with these exceptions:

5.5.3.1.1. Easier to see the “big picture” in front of the aircraft.

5.5.3.1.2. Turnpoints must be selected on the basis of distinct identification from higher altitudes. For example, choose the major highway interchange versus the dirt road/railroad intersection, or the mountain peak versus the small ridge.

5.5.3.1.3. Weather must be considered as well (for example, low fog).

5.5.3.2. Cockpit Tasking. Medium-altitude ingress allows the pilot, based on task load, to fixate inside the cockpit for longer periods of time. More radar work can be accomplished; more time is available to monitor the cockpit displays. Medium altitude may be the correct option when the major threat is AAA.

5.5.3.3. Medium-Altitude Advantages:

5.5.3.3.1. Better range and endurance potential.

5.5.3.3.2. Threat avoidance from certain systems; especially AAA and manportable air defense systems (MANPADS).

5.5.3.3.3. Easier navigation when weather is not a factor.

5.5.3.3.4. Higher potential energy.

5.5.3.3.5. More time available to work aircraft systems and to interpret and recognize details from target study.

5.5.3.3.6. Simpler attack geometry is possible.

5.5.3.4. Medium-Altitude Disadvantages:

5.5.3.4.1. Vulnerable to certain threat systems.

5.5.3.4.2. Easier detection by threat due to radar LOS.

5.5.3.4.3. Threat is not isolated above you; 3-dimensional threat attack axis exists.

5.5.3.4.4. Less aircraft performance dependent on configuration.

5.5.3.4.5. Air-to-air missiles (AAM) have longer ranges.

5.6. Computed Visual Bombing. Although the computed weapons delivery capability of the F-16 can make up for imprecise pilots, the system can get bombs closer to the target by flying smooth, accurate parameters. The planned parameters ensure frag clearance, desired impact angle, fuze arming, or burst/function altitude for weapons. Varying the dive angle changes fuze arm, safe escape, and minimum recovery altitudes. A running aim-off distance (AOD) due to improper G can produce an excessively fast pipper ground track and prevent a good bombing solution. A steady AOD slows the pipper ground track rate and provides a better bombing solution, improving accuracy.

5.6.1. Choosing a Delivery Option.

5.6.1.1. The F-16, with its sophisticated avionics package, gives the pilot several visual bomb delivery options. The method of delivery is dependent upon the aircraft systems available. Specifically, ordnance is typically released in the following ways:

- CCRP.

- LADD
- CCIP.
- DTOS.
- VIP
- Strafe.
- Manual Delivery.

5.6.1.2. A computed delivery is obviously preferred due to its accuracy and independence from pre-calculated dive angles, airspeeds, altitudes, and winds. Computed delivery is dependent, however, upon the following:

•An operable FCC.

•Accurate INS alignment (good INS velocities).

•An accurate ranging reference (radar, system altitude, targeting pod (TGP), RALT, etc.).

5.6.2. Manual Delivery. If the MMC has partial failure, there is no choice other than to deliver manually. This can be done with the help of the HUD, which will still provide airspeed and altitude scales along with pitch lines. If AGR is bad (or the FCR has failed), the FCC will automatically use BARO ranges. BARO requires an accurate system altitude. Perform an ACAL if possible.

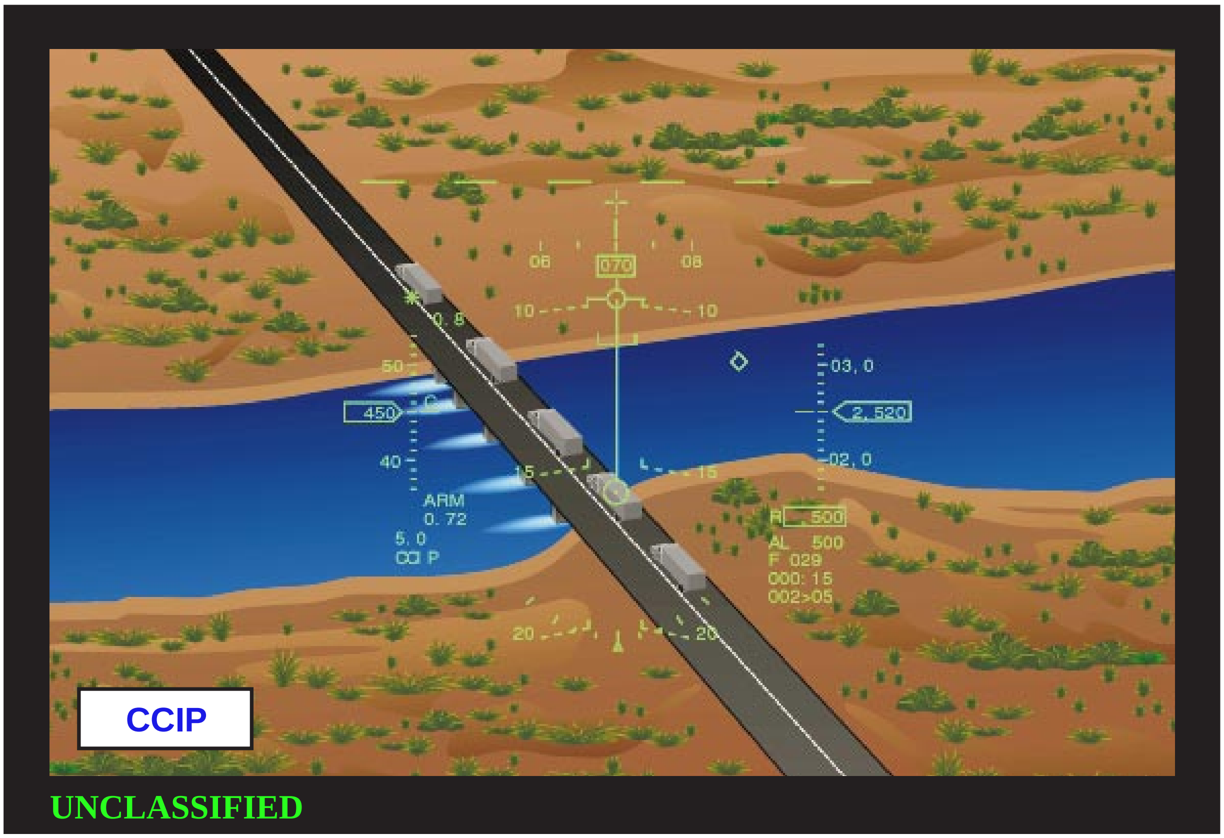
5.6.3. Target Study. In order to identify the target you have to know what it looks like. The type of delivery and weapon used will tailor your target study. All pilots should be very familiar with their assigned desired mean point of impact (DMPI) and back-up DMPIs through target photographs and map study.

5.6.4. Dive Recovery. Any ordnance delivery requires a proper recovery for three basic reasons: (1) to avoid the weapon frag envelope, (2) to avoid hitting the ground, and (3) for safe separation. Perform the correct planned recovery maneuver on every pass, as described in the Dash 34. Plan to release at or above the MRA or abort the delivery.

5.6.5. Continuously Computed Impact Point. Initiate the CCIP delivery mode by selecting air-to-ground. Verify the appropriate attack profile, correct weapon, single/pair option, number of release pulses, spacing, and fuzing selection prior to roll in (preferably at FENCE check and the IP). Place the Master Arm switch to MASTER ARM and check for a SMS RDY indication and ARM in the HUD. Select the target steerpoint to ensure correct target elevation if the system reverts to BARO. From CCRP, with roll-in parameters met and the target positively identified, select CCIP by depressing the Missile Step button. Use a smooth roll in and roll out, compensating for the wind. Concentrate on pulling the FPM toward the aim-off point and ***not*** directly to the target. Lead the roll out to put the bomb fall line (BFL) through the target with the appropriate target-to-BFL relationship—this will pay off in the tactical environment. Once the BFL relationship/AOD has been set, hold the AOD/FPM on that spot and allow the CCIP pipper to approach the target as you steer out any azimuth errors. Do not pull the FPM up in an effort to rush the pass unless you predict pickling below your planed minimum release criteria. This “banana pass” will result in a higher than planned release, and degrades delivery accuracy. If you determine the pipper will not get to the target before MRA, decrease the dive angle by increasing the AOD. (See **Figure 5.3.**, CCIP.)

5.6.5.1. Pickle Technique. Pickle when the CCIP pipper reaches the target. Pickle and hold your release G until all bombs are released. Avoid the tendency to "quick pickle" as this could inhibit release with a delay cue or result in a partial release. A technique to avoid this is to hold the pickle button down until initiating the turn during and after the safe escape maneuver (SEM).

Figure 5.3. CCIP.



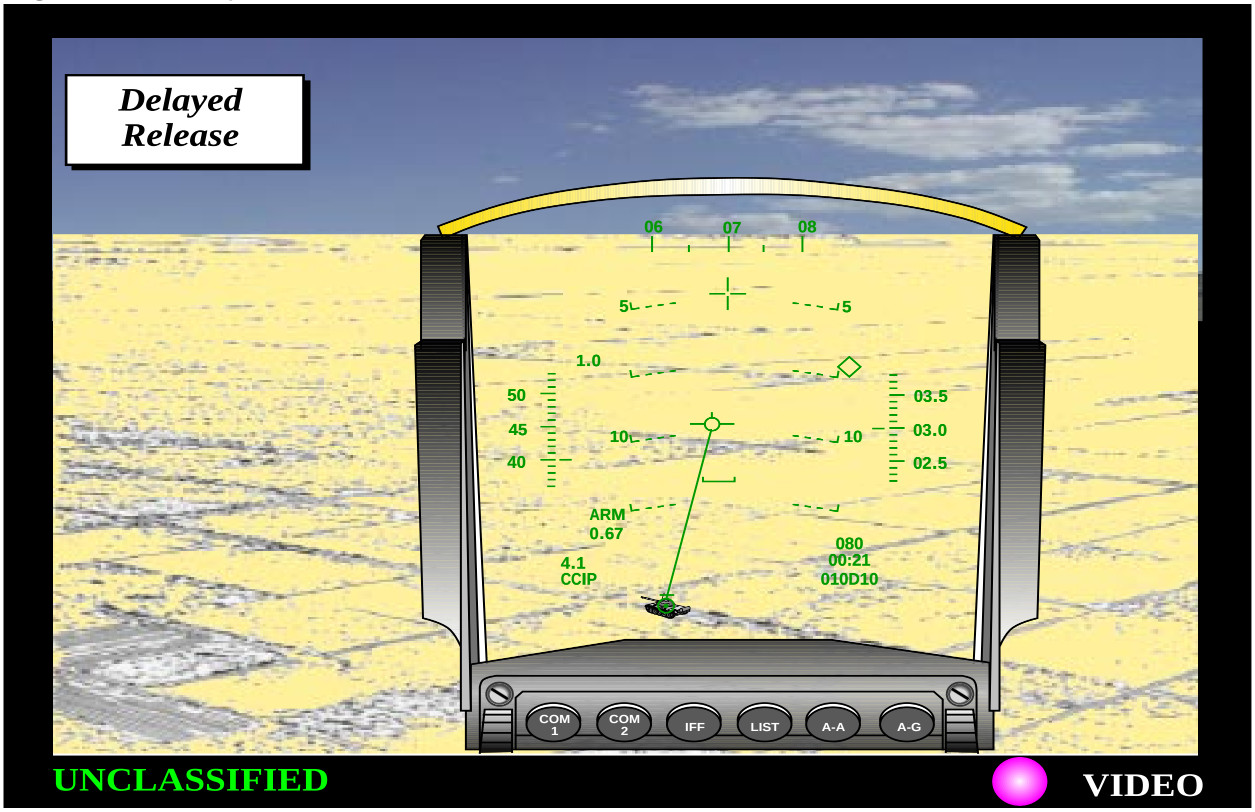
5.6.5.2. Winds. Since CCIP is a computed delivery mode, the effects of winds are automatically compensated for by the FCC wind model. The pilot's job is to get the pipper over the target, to do that, consider the winds. The headwind/tailwind component is automatically corrected for by the FCC moving the CCIP pipper up or down along the BFL. Adjust the base position to compensate for winds to ensure the correct dive angle is achieved. If there is a headwind on your attack/roll in axis then move your base position closer to the target. If a tailwind is resent, then move your base position farther away.

5.6.5.3. Crosswinds. Most of the crosswind correction is made by drift stabilization of the FPM and associated symbology. As long as the drift cutout switch is in the NORM position, the technique of placing the FPM upwind and the BFL through the target will cause the nose of the aircraft to crab into the wind. This crabbing causes the aircraft to fly over the target, thus compensating for most of the crosswind. The BFL will be sloped to the downwind side. Under these conditions you may wish to place the BFL slightly upwind of the target on the initial roll out. Do not use drift cutout while in the CCIP mode. If drift cutout is selected, the FPM and BFL will not be displaced downwind; however, the pipper will still show the impact point. Thus, the line between the FPM and pipper will be angled excessively, the aircraft will be in a near-constant bank to keep the target under the BFL.

5.6.6. Continuously Computed Impact Point Delayed Release. For release conditions where the bomb impact point is below the HUD, the CCIP pipper cannot be positioned low enough at the instantaneous impact point. In this situation, the CCIP pipper is positioned approximately 14 degrees below the boresight cross and a time delay is computed, based on the difference between the pipper position and the actual impact point. The presence of the delay cue indicates that this situation exists. The delay cue is weapon and aircraft parameter dependent, but you can generally expect a delay cue if your planned attack calls for a manual mil setting greater than 230 mils. Strong headwinds, shallow dive angle, and slow airspeed on the attack are also parameters that commonly lead to delay cues. This delivery is the same as the normal release until the point of pickle. If the delay cue is present, hold the pickle button depressed. Steering symbology will appear, the CCIP pipper will remain over the target. Fly the FPM to the steering line to null any steering error while holding the pickle button. Release will occur when the solution cue reaches the FPM. In most situations the delay will be very short (less than 1 second) and post-designate symbology may not be apparent prior to release. Ensure that maximum employment G is not exceeded prior to release while executing the dive recovery if minimum altitudes are approached. Release has occurred when the FPM begins flashing coincident with the actual release of ordnance. It is a good habit to hold the pickle button down until well after release (technique: FPM through the horizon). This ensures that you will get all bombs off when rippling a string of bombs. ***WARNING***: To minimize the possibility of an accidental live AAM firing, release the pickle button before switching to an air-to-air mode. (See **Figure 5.4.,** Delayed Release.)

5.6.7. Dive Toss. The DTOS mode is used primarily to accomplish low altitude toss (LAT) deliveries. Initiate DTOS by selecting air-to-ground, the appropriate attack profile for the weapon, and the DTOS delivery mode. The Missile Step button is used to step to DTOS from CCIP or CCRP. Verify single/pairs release pulses, spacing, and fuzing. Recheck Master Arm switch to MASTER ARM, RDY on SMS, and DTOS and ARM in the HUD. Plan a longer final than is used for CCIP or manual events. Also check the steerpoint selected. If the radar works properly, the steerpoint will not be important. But, if the radar breaks lock for 3 seconds, the FCC will use the elevation of the steerpoint as the target elevation when computing a BARO solution. Roll out on final with the aircraft flight path directly in line with the target. Designate the target by pickle or designate to ground stabilize the TD box and then slew it to the target. When using pickle and hold to designate, avoid slewing to a release solution due to over controlling of the TD box (i.e., if you designate and then slew closer to you, you may get a release inside of minimum range). Get on steering and ensure you hold the pickle button down when the solution cue approaches the FPM. Execute a frag avoidance maneuver after bomb release occurs to adhere to recovery minimums plus vertical or horizontal separation of the bomb frag. Know minimum stand-off range and ***do not violate it***!

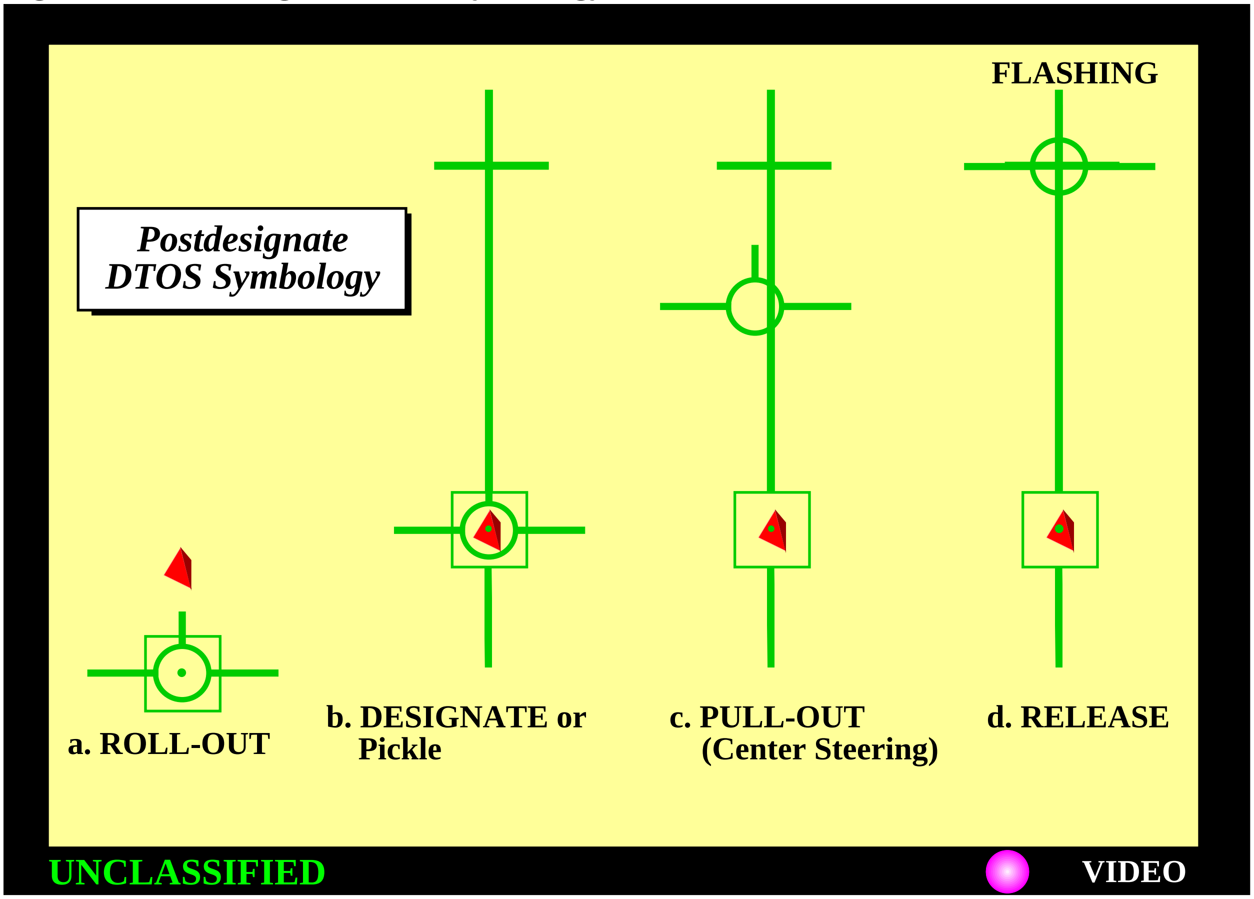
Figure 5.4. Delayed Release.



5.6.7.1. DTOS Symbology. After the TD box is ground stabilized over the target azimuth errors are controlled by steering the FPM to the steering line. When the target is at maximum toss range, a solution cue appears on the HUD along the steering line. The maximum toss solution is based on the assumption that an instantaneous 5-G pull will be made to a 45-degree climb angle. Pulling greater than 5 Gs may result in short bombs or no release at all and, with some weapons, may exceed the stores limits. During a long range DTOS delivery, a maximum toss anticipation cue (100 milliradian circle) is displayed on the HUD 2 seconds prior to the solution cue display. When the solution cue is displayed, the anticipation cue flashes for 2 seconds, then disappears. Time-to-go to release is displayed in the lower right corner of the HUD. Bearing (in tens of degrees) and range to target are also displayed. As time-to-go approaches zero, the solution cue will move downward toward the FPM. Automatic release occurs when the solution cue intersects the center of the FPM, provided the pickle button is depressed. The FPM will flash at release. (See **Figure 5.5.**, Postdesignate DTOS Symbology.)

5.6.7.2. Point-Blank Aiming. Point-blank aiming (TD box on FPM) is the simplest DTOS method from a mechanical pilot skill standpoint. You can also "preslew" the TD box below the FPM. Some pilots find this helps them get the TD box on the target, but be aware of pendulum effect. When you designate, the TD box becomes ground stabilized and you can continue to slew to refine aiming. Designating with the pickle button and holding it until release is the easiest method. If designating with the designate switch, depress the pickle button prior to the solution cue reaching the FPM. Hold the pickle button depressed until the solution cue intersects the FPM and the FPM begins to flash to indicate release. The FPM will continue to flash until the pickle button is released.

Figure 5.5. Postdesignate DTOS Symbology.

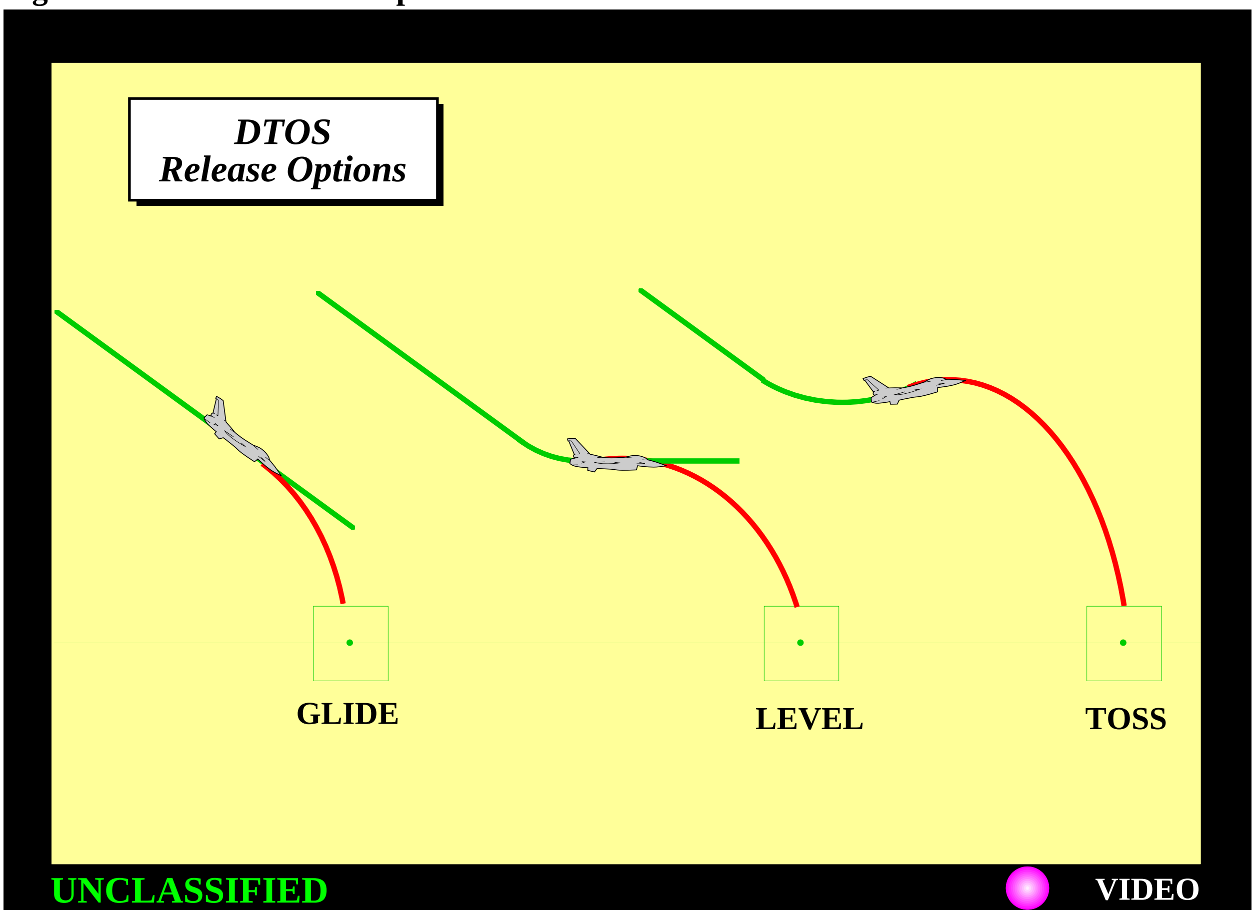


5.6.7.3. Climbing Release. Initiate a smooth pull keeping the FPM centered on the steering line. Continue to pull to remain outside the minimum release slant range. This can result in a toss, glide, or level release. After designation in point-blank aiming, watch the TD box for drift as you approach release. If toward 6 or 12 o'clock, an error is probable. If drift is small, refine aiming using the radar cursor/enable button to place the TD box back on the target. Note that movement toward 12 o'clock, followed by movement toward 6 o'clock is normal. If the TD box is off more than 5,000 feet laterally, the release will be inhibited. Recage the TD box by either exiting the DTOS mode. If you choose not to recage, the TD box will remain ground stabilized. INS drift may cause the TD box to move. (See **Figure 5.6.**, DTOS Release Options.)

5.6.7.4. Slew Aiming. The method shown in **Figure 5.7.** Slew Aiming, provides maximum flexibility in tactical situations, but mastery is more difficult. It is possible to slew aim regardless of aircraft attitude as long as the aimpoint is within the HUD FOV. Remember that directional control of the TD box is always referenced to aircraft attitude. Develop slew aiming skill as follows:

- Roll out on final with the TD box on or near the target. One technique is to roll out with the TD box short of the target and smoothly pull it up to the target.
- Ground stabilize the TD box (designate or pickle).
- Adjust power, if necessary.
- Slew the TD box to the target. Use the cursor/enable button to slew the TD box.
- "Fly" the FPM toward the steering line and select a release option based on range to the target.
- Continue to fly the FPM to the steering line until release.

Figure 5.6. DTOS Release Options.



5.6.7.5. Azimuth Error. Observe the solution cue progress, keep the FPM on the steering line, and complete the delivery as described in point-blank aiming. If you have neglected to fly out the azimuth error while slew aiming and the solution cue is approaching the center of the FPM, you have three options:

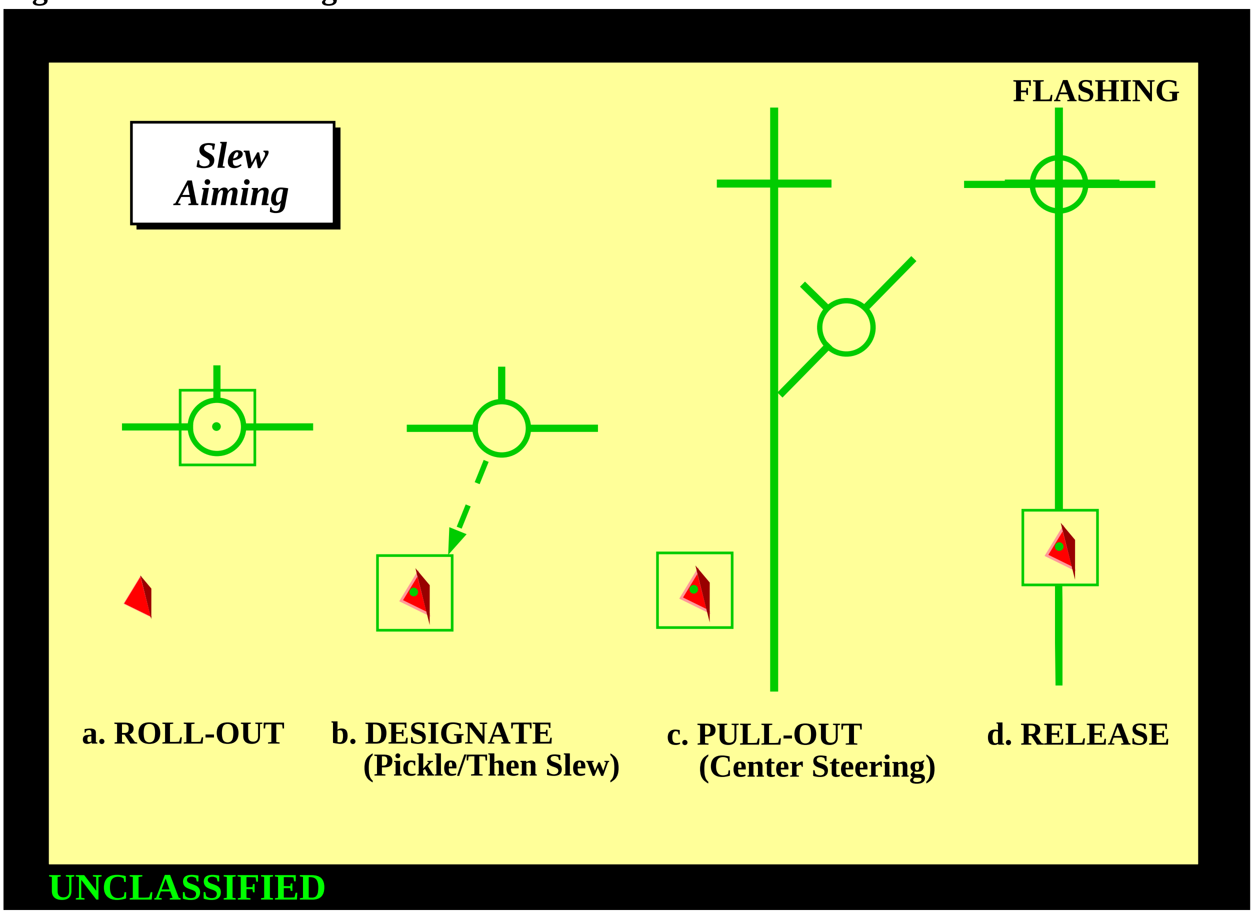
5.6.7.5.1. Abort the release (thumb off pickle button).

5.6.7.5.2. Accept the error. If the error is more than 5,000 feet laterally, the release will be inhibited.

5.6.7.5.3. Fly out as much of the error as possible and accept the result. The closer the FPM is to the steering line, the better. Be careful not to violate current Dash 1 release limitations for the type bomb you are dropping.

5.6.7.6. Refining TD Box Position. Continue to slew after designation. In this case the TD box is ground stabilized, move it over the ground rather than in relation to the FPM. In addition, each time you slew, the FCC takes a new range sample. Be extremely careful when slewing with the pickle button depressed; if slewing to 6 o'clock, the system may “see” a solution and release before you have a chance to correct. Refine TD box placement prior to initiating the pull up for a climbing release to minimize G-induced TD box lag in the HUD.

Figure 5.7. Slew Aiming.



5.6.8. Computed Bombing Error Management. While the complexity of the system does not allow for easy error analysis, there is a way to organize computed error analysis which will not only improve your bombs, but also result in better write-ups, and better systems lead to better bombs. GP bombs are far more accurate in delivery than BDU-33 practice munitions. Do not let the accuracy of BDU bombs in DTOS give you a false sense of inaccuracy with GP weapons. There are three main sources of error when the F-16 drops a bomb: you, the INS, or ranging.

5.6.8.1. Pilot Error. Before you blame the INS or change the ranging mode, check yourself:

5.6.8.1.1. Did you really designate/pickle with the TD box/CCIP pipper stabilized on the desired aimpoint?

5.6.8.1.2. Were you pushing and pulling on the stick after designation?

5.6.8.1.3. Accurate error analysis depends on having consistent parameters on each pass.

5.6.8.2. INS or Ranging Errors. Once satisfied that you are not the problem, there are some things you can do to determine whether the INS or the ranging mode is at fault. The first step is to understand these basic principles:

5.6.8.2.1. Ranging errors cause 6/12 o'clock misses only.

5.6.8.2.2. INS errors may be in any direction.

5.6.8.2.3. The magnitude of an INS error depends on the time from designation to bomb impact (longer weapon range will equate to greater error).

5.6.8.2.4. Correcting DTOS box placement on subsequent passes is fairly straight forward. (See **Figure 5.8.**, DTOS Error Correction.)

5.6.8.3. CCIP Analysis. The most common method for CCIP error analysis is the actual bomb impact versus the pipper placement at pickle. Large misses short or long are probably a ranging problem. Small misses short or long could be a ranging problem or boresight error. Rule of thumb: to correct a known error simply correct that same distance in the opposite direction. This can be accomplished by using offset aiming of the pipper or by using the Delta Bomb Range mode for long/short and left/right corrections.

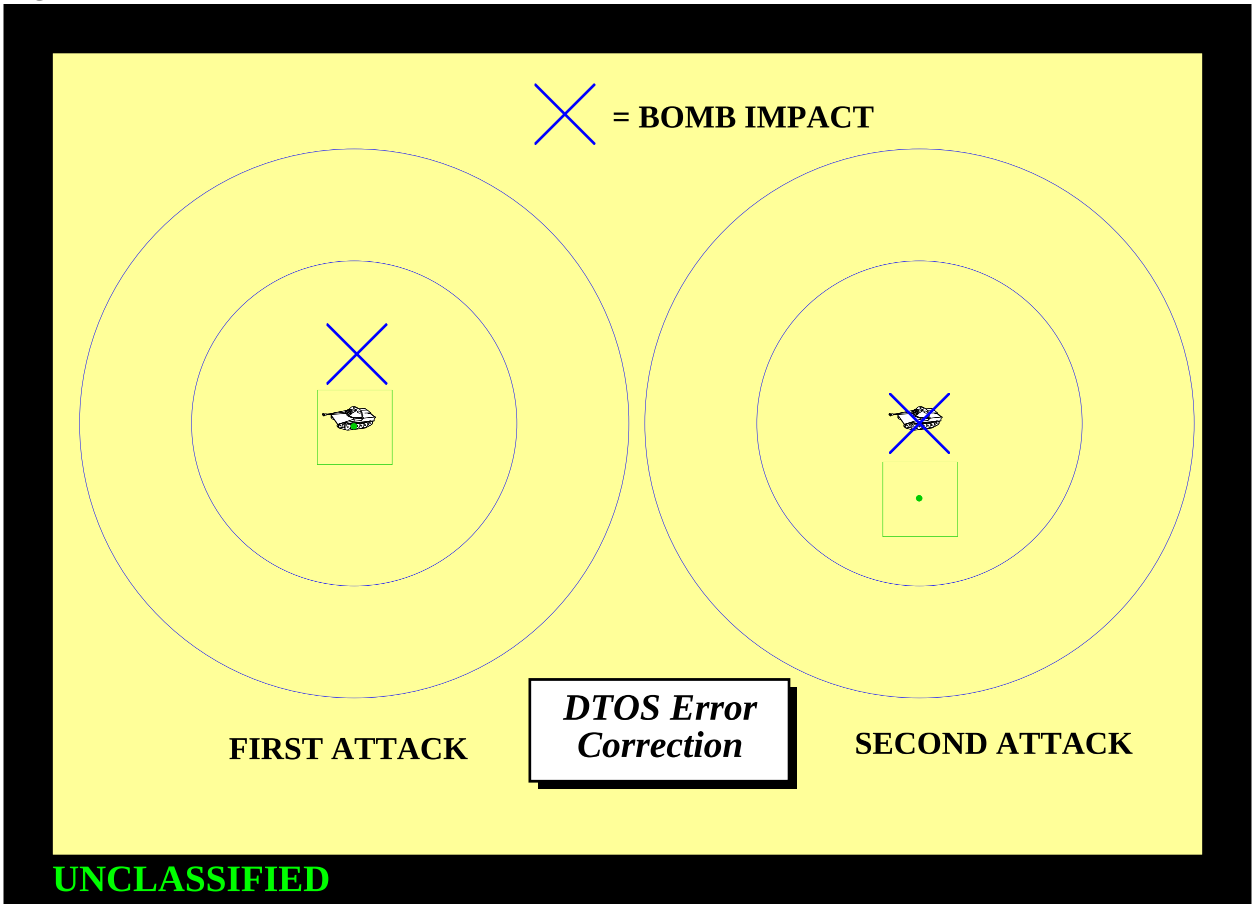
5.6.8.4. Canopy Coefficients/Boresight. Canopy coefficients are applied to the CCIP pipper and TD box, but not to the BFL. This sometimes results in what appears to be a misalignment of the symbology under certain conditions. For example, the CCIP pipper may not appear exactly on the end of the BFL. This is not unusual. Use the CCIP pipper for aiming even if it is slightly misaligned with the BFL. Bombing errors may be the result of inaccuracies in the coefficients that correct for canopy errors. Squadrons should have a current listing of aircraft specific values used to verify coefficients. Verification is accomplished by accessing the miscellaneous function on the FCNP. If the numbers are incorrect, insert the correct numbers into the FCC. Ask your squadron weapons shop where the most accurate coefficients are located.

5.6.8.5. Ranging Errors/Considerations. Selection of a ranging mode is critical when it comes to optimizing the hit probability. Several factors effect the choice of a ranging mode. Is AGR working? Is system altitude significantly off? Are there radar jammers in the target area? A proper air-to-ground system check accomplished prior to the target is crucial for determining the optimum delivery mode.

5.6.8.6. Ranging Mode Selection. Assuming all modes are operating properly, radar should be the primary ranging mode. If you suspect AGR is in error or inconsistent, and your system altitude is reasonable, BARO ranging may be preferable to radar ranging. For

BARO ranging, it is critical that the elevation of the selected steerpoint is equal to the elevation of the target and that system altitude is accurate. The effect of ranging and system altitude errors decreases with increased bomb impact angles.

Figure 5.8. DTOS Error Correction.



5.7. Manual Weapons Delivery. In the event of MMC degradation, you may be forced to resort to manual bombing. Good manual bombing demands rigid compliance with delivery parameters. There are many conditions that might force you into a manual delivery. Some of these conditions might allow limited use of the HUD, but in general you will only have the standby reticle and heads down instruments. If the HUD is operational, then the altitude, airspeed, and pitch scales (if available) may be useful in establishing parameters in certain circumstances.

5.7.1. Preparation and Planning. The following items should be accomplished even if manual bombing is not planned. The requirement to accomplish manual weapon deliveries is normally not predictable, so setting up your avionics for backup deliveries should become a normal habit pattern.

5.7.1.1. Before the flight:

5.7.1.1.1. Complete weapons employment data (AOD, mil setting, initial pipper placement [IPP]) on the line-up card.

5.7.1.1.2. Obtain current and forecast winds for each event.

5.7.1.1.3. Compute an upwind aimpoint for the pipper at release.

5.7.1.1.4. Determine the mil correction headwind/tailwind factors.

5.7.1.2. At the aircraft:

5.7.1.2.1. Turn on the standby reticle, confirm the aiming reticle is visible and set to the expected attack mil setting. ***NOTE***: a maximum of 260 mils can be dialed in the standby reticle.

5.7.1.2.2. Set up the SMS for a backup manual attack. One technique is to use “profile 2” in the SMS to have the capability to get to the manual delivery system with minimal switch changes. Make sure the correct intervalometer is set for the attack you intend to fly. The intervalometer sets the bomb spacing.

5.7.1.3. Range Entry. The following steps will ensure the pilot is ready and switches are set properly:

5.7.1.3.1. If possible, reference INS (or wingman's) for winds at altitude.

5.7.1.3.2. Obtain the latest surface winds if possible.

5.7.1.3.3. As necessary, re-compute the upwind aimpoint for each event or the headwind/tailwind mil correction factors.

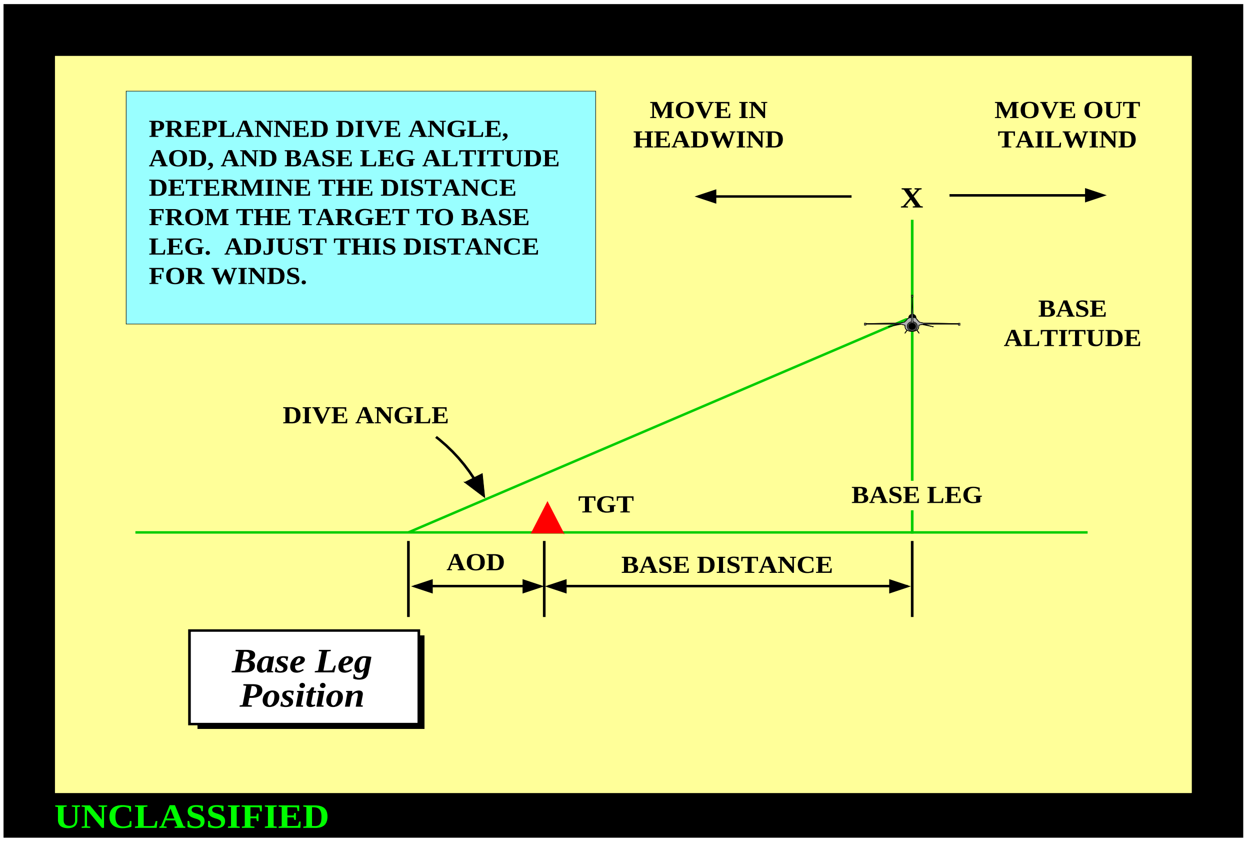
5.7.1.3.4. Set SMS to the MAN mode, position the Master Arm switch to MASTER ARM, turn on the standby reticle, and set the mil depression for the event to be flown.

5.7.1.3.5. Review parameters for the events to be flown.

5.7.2. Base Leg. The range wind (head/tail) determines the amount and direction of base leg position shift into the wind from the no-wind figures. The amount is dependent on the strength of the wind at both release and roll-in altitudes. Generally, adjust the base leg into the wind by about three times your computed upwind aimpoint. When you roll out on the adjusted base position, use crab to maintain that distance as you approach the roll in. Lead the turn to base to roll out at the right range. When you are tracking toward the correct roll-in point, start thinking about when to begin the roll in to roll out on final with the correct wind corrected flight path. (See **Figure 5.9..**, Base Leg Position.)

5.7.3. Final. Crosswinds on final will force you to use a crab method or a drift method to establish a ground track that will allow for a successful release point.

Figure 5.9. Base Leg Position.



5.7.3.1. Crab. Crab is recommended for low-angle deliveries, roll out directly on an extension of the attack direction line. This is called the attack axis. (See **Figure 5.10.**, Low-Angle Crab Correction.)

5.7.3.2. Drift. Drift is recommended for high-angle deliveries, use the “rule of three.” This rule of thumb will position the aircraft upwind so that the bomb track is pointed toward the target with the aircraft heading parallel to the attack direction. Look at the target and the release aimpoint. Imagine a line through the aimpoint parallel to the attack direction extending on back to base leg—you will want to be over this line at release. The distance between this line and the target represents the lateral drift of the aircraft and bomb during the time from release to impact. The time from roll out to release will be about twice this, as will the distance drifted during that time. Therefore, you will want to roll out upwind from the target, about three times the release offset distance. Reference this distance to the release aimpoint and imagine another line parallel to the first, twice as far upwind. Roll out over this second line. (See **Figure 5.11.**, High-Angle Drift.)

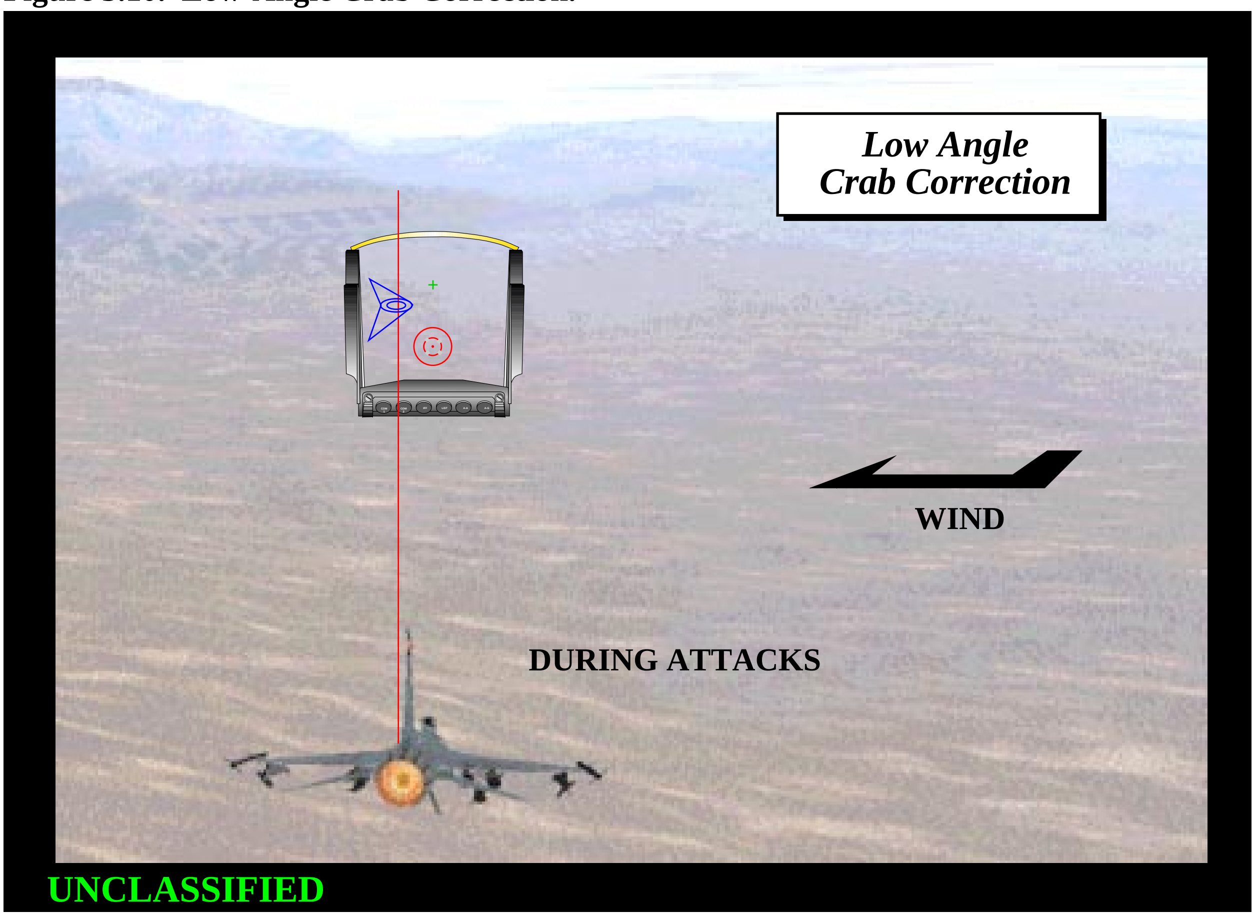
5.7.4. Manual Bombing (Dive). The roll in is much easier at the proper base leg position, altitude, and speed. The importance of “base leg” cannot be overemphasized; it is the basic geometric factor effecting the dive angle. One technique is to use one-half the planned dive angle plus 90 degrees for roll in bank (i.e., 105 degrees for a 30-degree dive). Keep your eyes on the target area and use back stick as necessary to make a hard turn in the delivery plane. Pull the nose directly to a point 12 o'clock to the target (the computed AOD). A common tendency is to “dish out” during the roll in, resulting in a shallow dive angle. This is caused by excessive bank during the roll in, allowing the nose to stabilize short rather than long of the target. If you must be off dive angle, it is better to be slightly steep than shallow.

5.7.4.1. Roll-Out. During the roll out, do not use the depressed pipper for azimuth control since even the slightest bank will cause a pendulum effect and give erroneous information. The FPM is a better reference for attaining the correct ground track through the target. If the FPM is not available, visualize your drift across the ground in relation to the reticle and adjust accordingly.

5.7.4.2. Initial Pipper Placement (IPP). As soon as you roll out on final, set the planned IPP at the appropriate IPP altitude and note the dive angle. This is the most important part of the final delivery pattern as this ensures that the pipper will arrive on the target at release altitude.

5.7.4.3. Power Corrections. Adjust throttle to set planned airspeed. One technique is to pull the power at the planned delivery airspeed minus the planned dive angle. (Example: for a planned release airspeed of 450 KCAS during a planned 30-degree dive angle, pull the throttle back to 420 KCAS.)

Figure 5.10. Low-Angle Crab Correction.



5.7.4.4. Wind Corrections. Make wind corrections by applying either the drifting or crab methods described earlier to arrive at a final solution with the pipper on the planned upwind release aimpoint for combat offset deliveries or on the 3/9 line for mil correction deliveries.

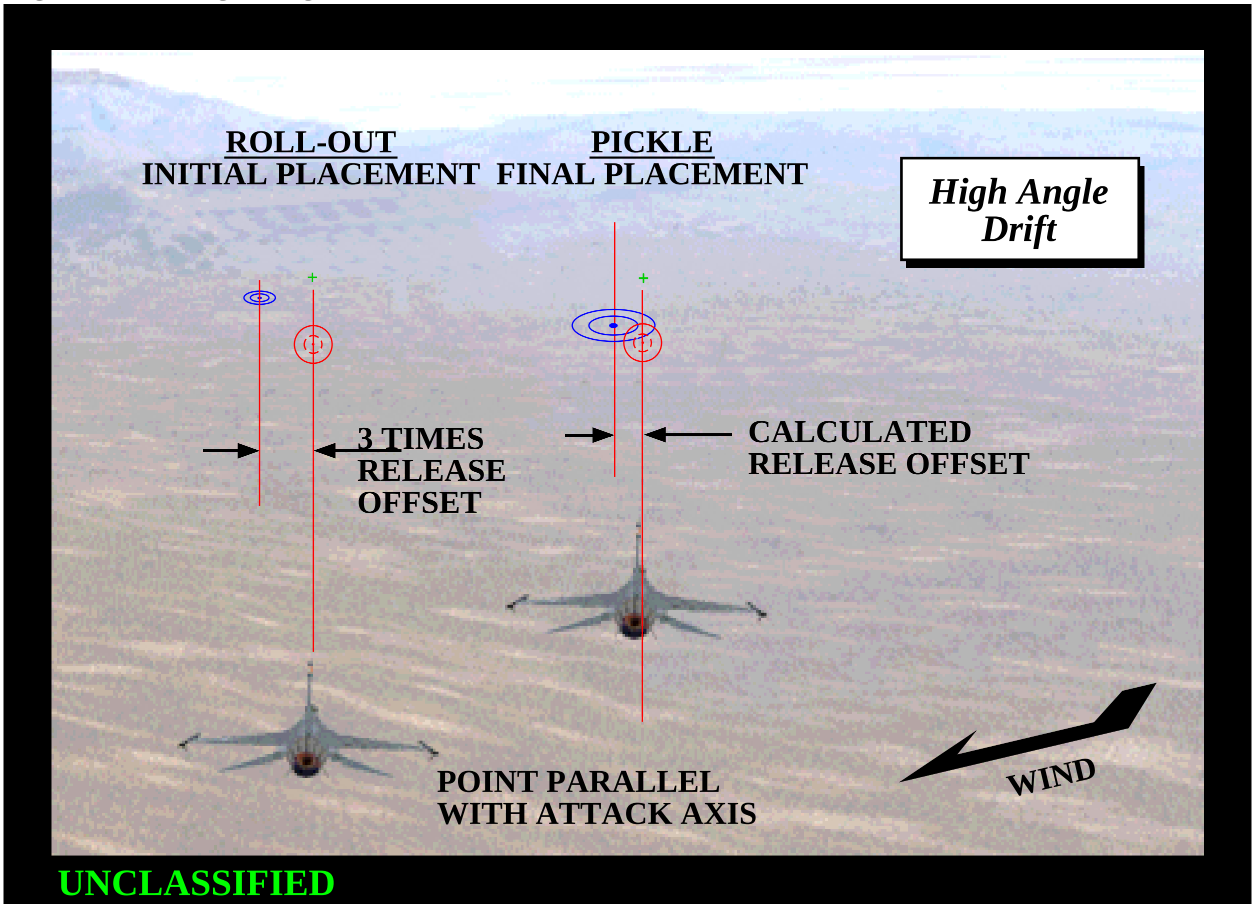
5.7.4.5. Final Corrections. Observe the rate of pipper track and altimeter decrease. If an accurate IPP has been set, the pipper would arrive at the upwind aimpoint at the preplanned altitude, airspeed, and dive angle. Since all these parameters are seldom met perfectly, adjust pickle altitude and/or sight picture to compensate. One technique of adjusting release for incorrect dive angle is to relate the change to a release altitude adjustment. With the correct AOD/IPP set, for every 1 degree steep, pickle 100 feet above the planned release altitude. This is a generalization that applies to all dive angles, with the intent of being easy to remember. Never release below the set MRA.

5.7.5. High-Altitude Manual Bombing. The high-altitude manual bombing picture is similar to the 30- degree pattern, but the release altitudes are higher to allow for a recovery above a given threat envelope. On base, set the appropriate canopy relationship sight picture for the dive event planned. Mentally prepare for the delivery by determining the AOP, IPP, and bomb release sight picture. Be aware of the fact that although the pattern is high, the dive angle is steeper and the aircraft accelerates more rapidly. The tendency to press is normal because of the higher pattern; do not press below the MRA.

5.7.6. Manual Low-Angle Bombing Events. The major differences between low-angle, low-drag and low-angle, high-drag deliveries are the release altitude and AOD. Low-drag events have higher release altitude and a longer AOD. For level deliveries, a crabbing approach is recommended versus a drifting approach for all level deliveries—it requires less effort to fly over the target. While high drag ordnance is generally released closer to the target than low drag ordnance, high drags have a longer bomb trail. The bottom line in crab versus drift approaches is to fly the aircraft over an upwind point so that the bomb hits the target.

5.7.7. Error Analysis. Since it is difficult to attain all the required release parameters simultaneously, you must understand the effect on bomb impact caused by not attaining one or more of the release parameters. Error analysis is essentially the same for all bomb deliveries; however, different dive angles produce errors of varying magnitude. Single dive bomb errors do not usually happen (i.e., a steep dive angle results in a lower release altitude and higher airspeed by the time you get the pipper on the target). The result is an unbelievably long hit. When discussing error analysis, assume the pipper is on the target with all but one of the other delivery parameters met. The following errors effect accuracy: dive angle, release altitude, airspeed, G loading, bank angle, and skid.

Figure 5.11. High-Angle Drift.



5.7.7.1. Dive Angle. If correct AOD is not established and release is made with the sight on target at the preplanned release altitude, impact errors caused by dive angle deviations are the largest and therefore most critical. A steeper than planned dive angle places the aircraft further forward in space when the pipper arrives on the target. This is the release point (RP) range error. In this situation, bomb trajectory is flattened, but not enough to compensate for the RP range error and a long hit results. The opposite effect is true for a shallower than planned dive angle, but the resultant short error is greater than a long error resulting from a steep dive angle. The most important fundamentals are to be at the correct roll in point and set the correct AOD which equates to proper dive angle. These are the greatest errors, and once set, all other errors become correctable. (See **Figure 5.12.**, Effect of Dive Angle on Bomb Impact.)

5.7.7.2. Release Altitude. This results in two partially canceling errors. The first is release-point range error in that the aircraft is further forward in space if release altitude is low with the pipper on the target. This gives a long impact. The other error is a bomb trajectory error. If release altitude is low, bomb trajectory is reduced, but still the bomb will hit long as this is the lesser of the two errors. Again, it must be assumed that the pipper is on the aimpoint and the other parameters of the release are met. It is simply a result of not holding AOD. (See **Figure 5.13.**, Effect of Release Altitude on Bomb Impact.)

5.7.7.3. Airspeed Error. Fast or slow release airspeed can result from such mistakes as the wrong power setting, incorrect airspeed on the base leg, improper roll in, and error in dive angle. The two factors that result from airspeed deviations are bomb trajectory change and angle of attack (AOA) change. The resultant impact error is cumulative. Higher than planned airspeed results in a flatter bomb trajectory and a long hit. Increased airspeed decreases AOA which increases effective depression, giving a late sight picture and a long hit. (See **Figure 5.14.**, Effect of Airspeed on Bomb Impact.)

5.7.7.4. Release G Error. Each delivery has a preplanned G-loading at release. This G is a function of the cosine of the dive angle. It is not a factor read on a gauge in the cockpit during release, but a “seat-of-the-pants” thing. To release a bomb with other than the preplanned G on the aircraft changes aircraft AOA, thus changing effective depression. In a normal approach, the pipper is moved to the target at a rate so it reaches the aimpoint as other release conditions are attained. If the sight picture is attained too early and the pipper is held on the aimpoint, you will begin to decrease release G, decrease AOA, increase effective depression and get a long hit. Also, if you hold the bunt long enough, you may change your dive angle and this will add to the long impact. More G than planned (i.e., pulling the pipper up the aimpoint) results in a short hit. (See **Figure 5.15.,** Effect of Improper G Force on Bomb Impact.)

5.7.7.5. Bank Angle. A fairly common error in bombing deliveries is releasing with a wing low. A slight bank is difficult to recognize when the horizon is 30 degrees or more above the flight path. But, if the aircraft is banked at release, the sight picture is erroneous. This is due to the pendulum effect of the depressed sight. As the aircraft is banked, the sight swings in the opposite direction. With the pipper on the target under these conditions, the bomb will hit short and in the direction of the bank because the aircraft's flight path is not towards the target and the slant range to target is increased. (See **Figure 5.16.**, Effect of Bank Error on Bomb Impact.)

Figure 5.12. Effect of Dive Angle on Bomb Impact.

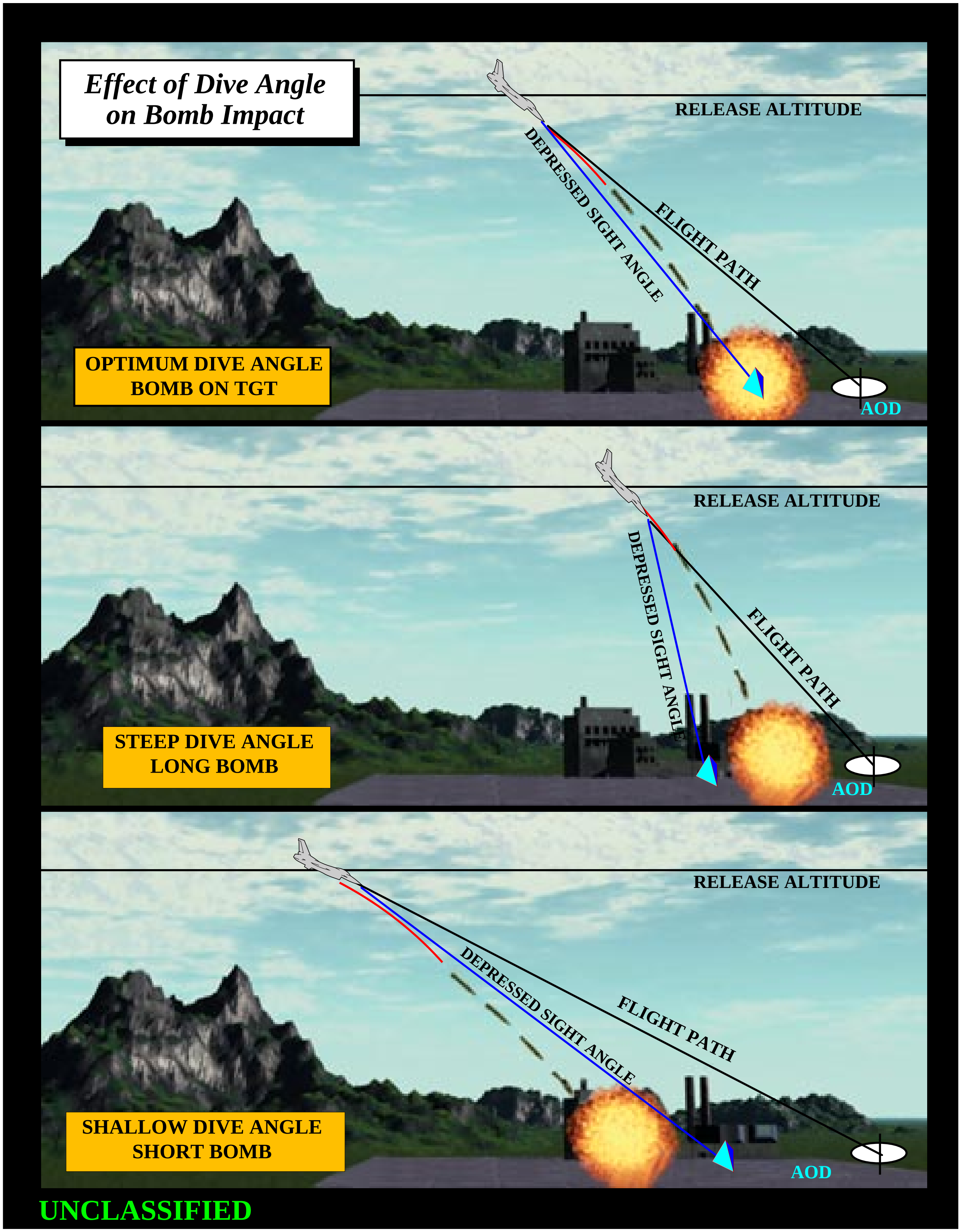
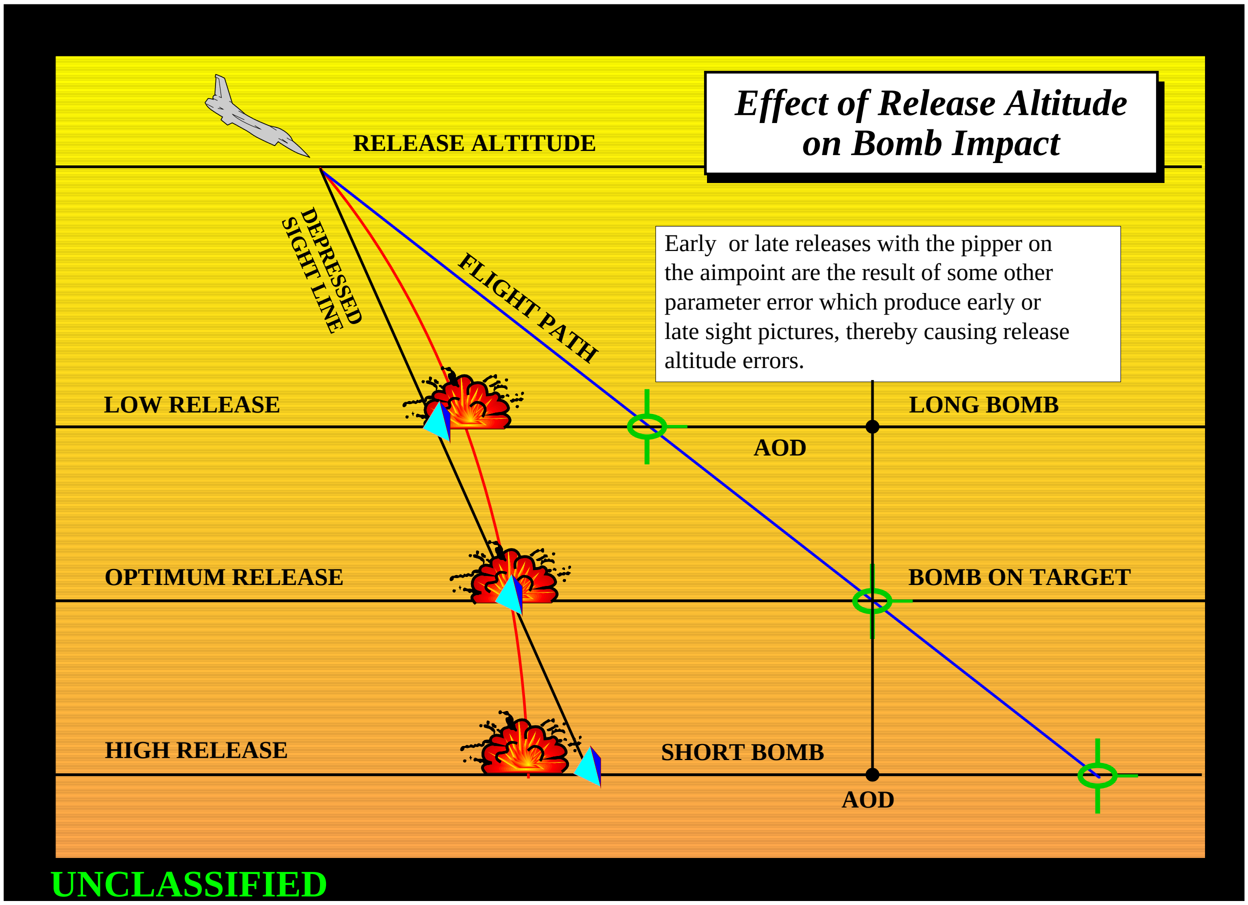


Figure 5.13. Effect of Release Altitude on Bomb Impact.



5.7.7.6. Skid. Release during uncoordinated flight causes an erroneous sight picture. In any bomb delivery, the bomb follows the flight path when released. If the ball is out to the right, the bomb will impact to the right. A last-ditch rudder correction to obtain the proper sight picture is not going to bring the bomb over to the target. The sight line and ground track must be parallel for the bomb to hit where the pipper is placed. The bomb will go long, in the direction of the skid.

5.8. Tactical Considerations. Attack selection is critical to mission success. A combination of variables drive attack selection: weather, weapon type, target, destruction level, and impact requirements, to name a few.

5.8.1. Visual Level Delivery. The visual level delivery (VLD) profile is essentially a level delivery or very shallow dive similar to that used for high-drag weapons. (See **Figure 5.17.**, VLD Delivery.) However, parameters for adequate fuze arming and safe escape become much more critical due to the weapon TOF. F-16 ballistics tables and CWDS have minimum release parameters for various fuze settings. CCIP is the recommended delivery mode.

Figure 5.14. Effect of Airspeed on Bomb Impact.

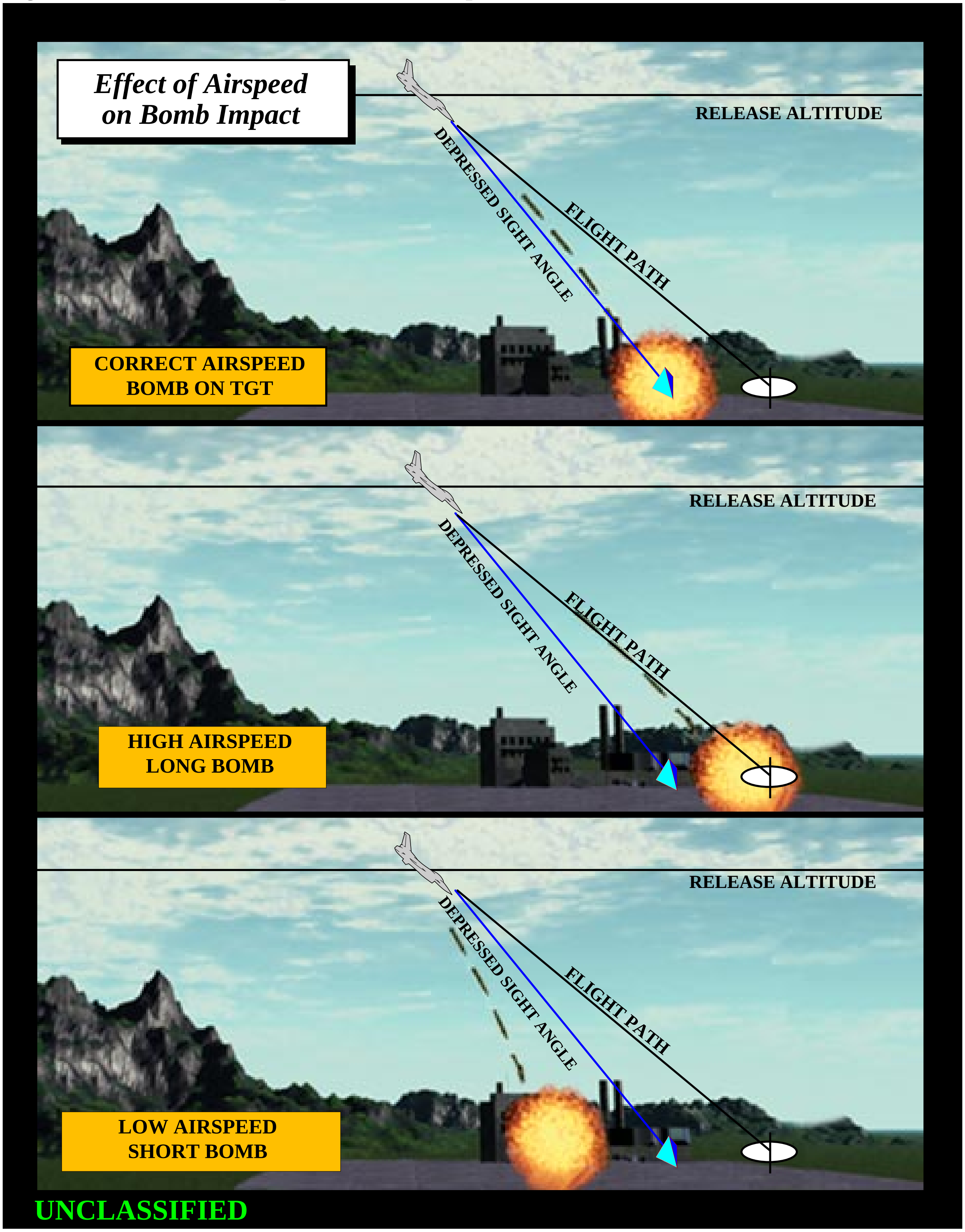


Figure 5.15. Effect of Improper G Force on Bomb Impact.

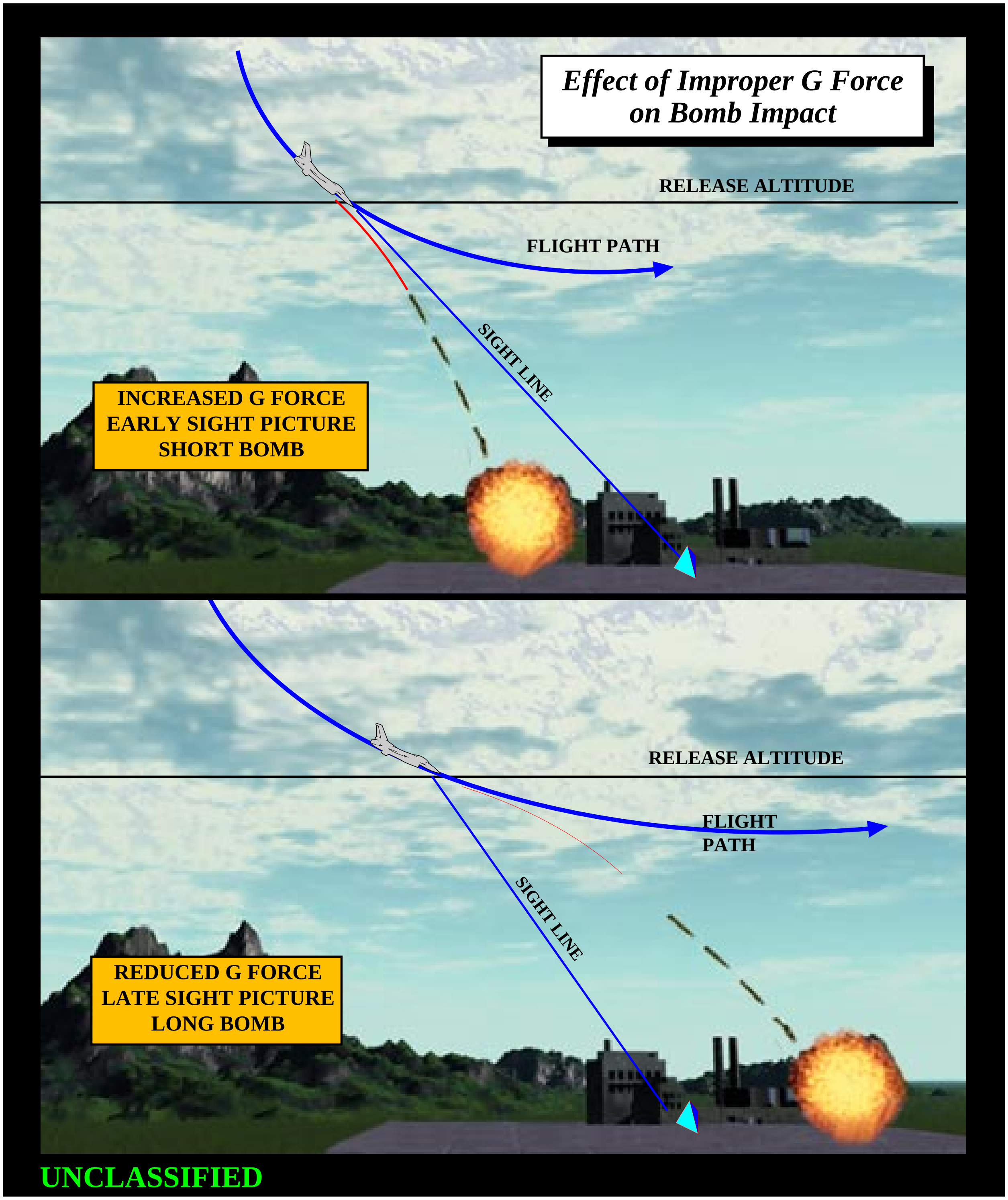
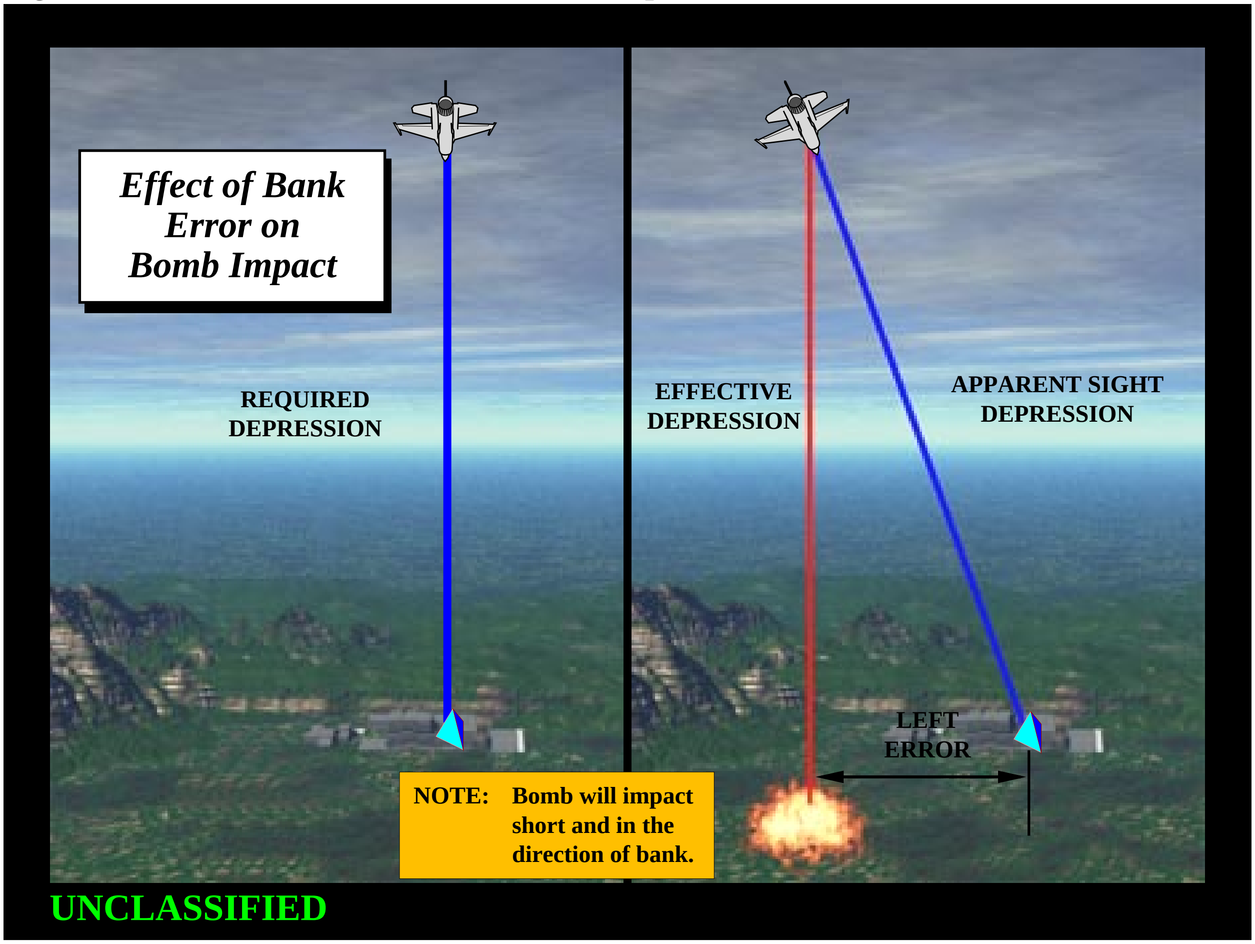


Figure 5.16. Effect of Bank Error on Bomb Impact.



5.8.1.1. Advantages:

5.8.1.1.1. Exposure time is minimal.

5.8.1.1.2. Navigation is direct to the target. No offset is required.

5.8.1.1.3. Reduces acquisition time for threat systems.

5.8.1.2. Disadvantages:

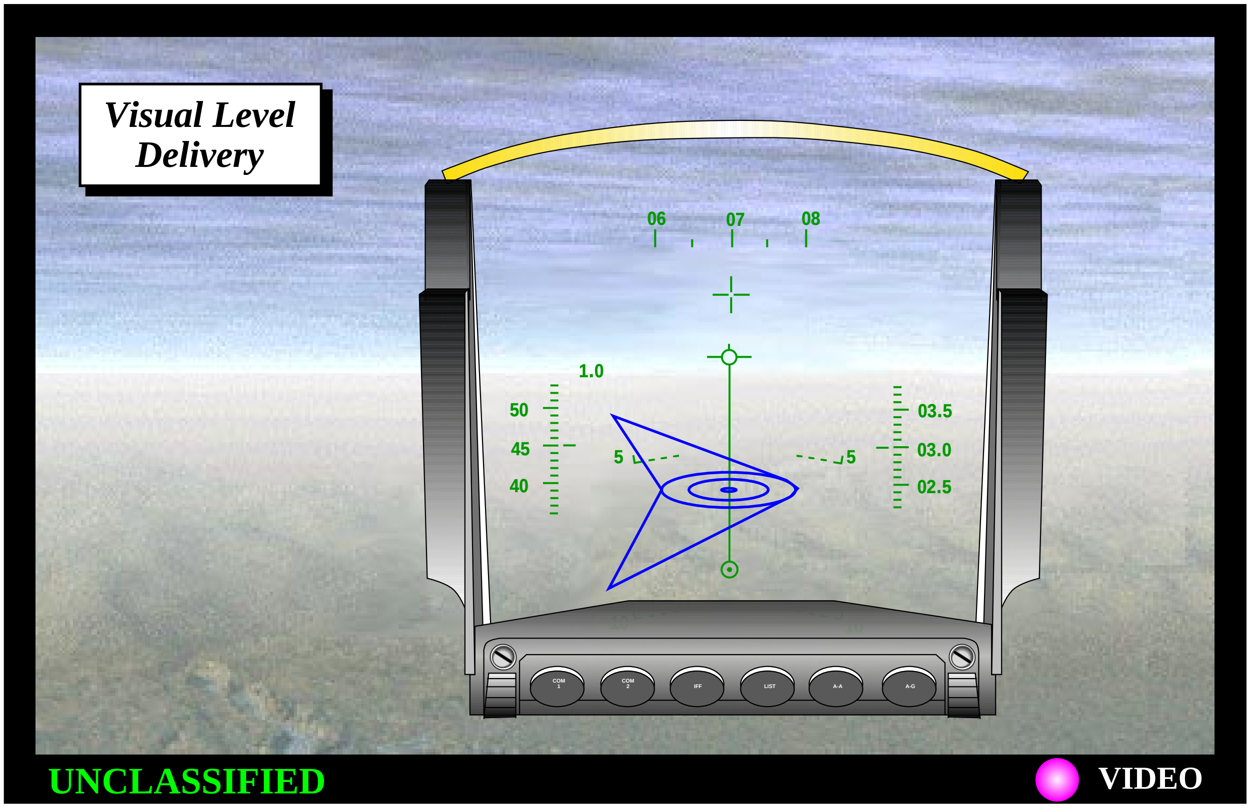
5.8.1.2.1. Target acquisition is difficult.

5.8.1.2.2. Low impact angle may reduce weapons effectiveness.

5.8.1.2.3. The minimum altitude for fuze arming and frag clearance is easy to violate.

5.8.2. Low-Angle Deliveries and Dive Bomb. Dive bomb (DB) is a delivery using 30 degrees or steeper dive. Low-Angle Low-Drag (LALD) and Low-Angle High-Drag (LAHD) deliveries are for any dive angle less than 30 degrees. Roll-in altitude is achieved through a pop-up, fly-up, or medium-altitude ingress. (See **Figure 5.18.**, Low Angle Deliveries.)

Figure 5.17. VLD Delivery.



5.8.2.1. Advantages:

5.8.2.1.1. Increased bomb impact angle with improved penetration effectiveness over low angle deliveries for DB deliveries.

5.8.2.1.2. Increased accuracy due to lower slant range and increased radar graze angle.

5.8.2.1.3. Increased time for target acquisition.

5.8.2.1.4. LAHD allows lower altitude operation while increasing bomb impact angle.

5.8.2.1.5. Radar-fuzed CBU weapons may be delivered effectively with DB and 20 degrees LALD.

5.8.2.2. Disadvantages:

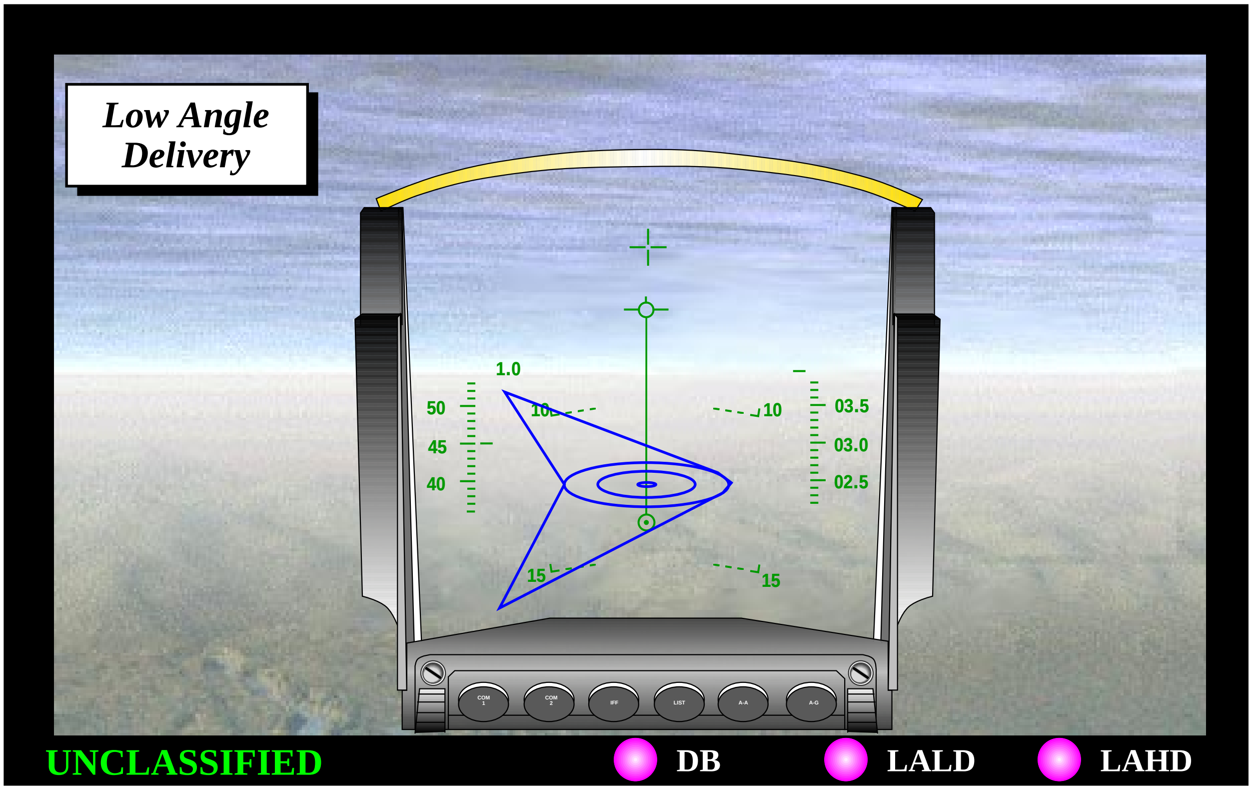
5.8.2.2.1. Exposure to MANPADS and AAA increases significantly.

5.8.2.2.2. Lower impact angles for low angle deliveries.

5.8.2.2.3. Significant delay cues for 10 degrees LALD CBU employment.

5.8.3. High-Altitude Release Bomb and High-Altitude Dive Bomb. High-altitude release bomb (HARB) and high-altitude dive bomb (HADB) are deliveries from medium or high altitude, preferably using 30 degrees or steeper dive. Roll-in altitude is typically achieved from a medium-altitude ingress. Problems associated with HARB and HADB include high crosswinds, lateral miss bomb release inhibit (if using CCRP), delay cues, and high G releases due to delay cues. In addition, weapons effects may vary greatly from those expected at lower release altitudes. Increased slant ranges, longer radar ranging, and high transonic release airspeeds all result in unpredictable bomb separation effects, cluster munition patterns and unpredictable weapon impact points. (See **Figure 5.19.**, High Angle Deliveries.)

Figure 5.18. Low Angle Deliveries.



5.8.3.1. Advantages:

5.8.3.1.1. Increased bomb impact angle and penetration.

5.8.3.1.2. Increased time for target acquisition.

5.8.3.1.3. Recoveries may be accomplished above small arms/light AAA threats.

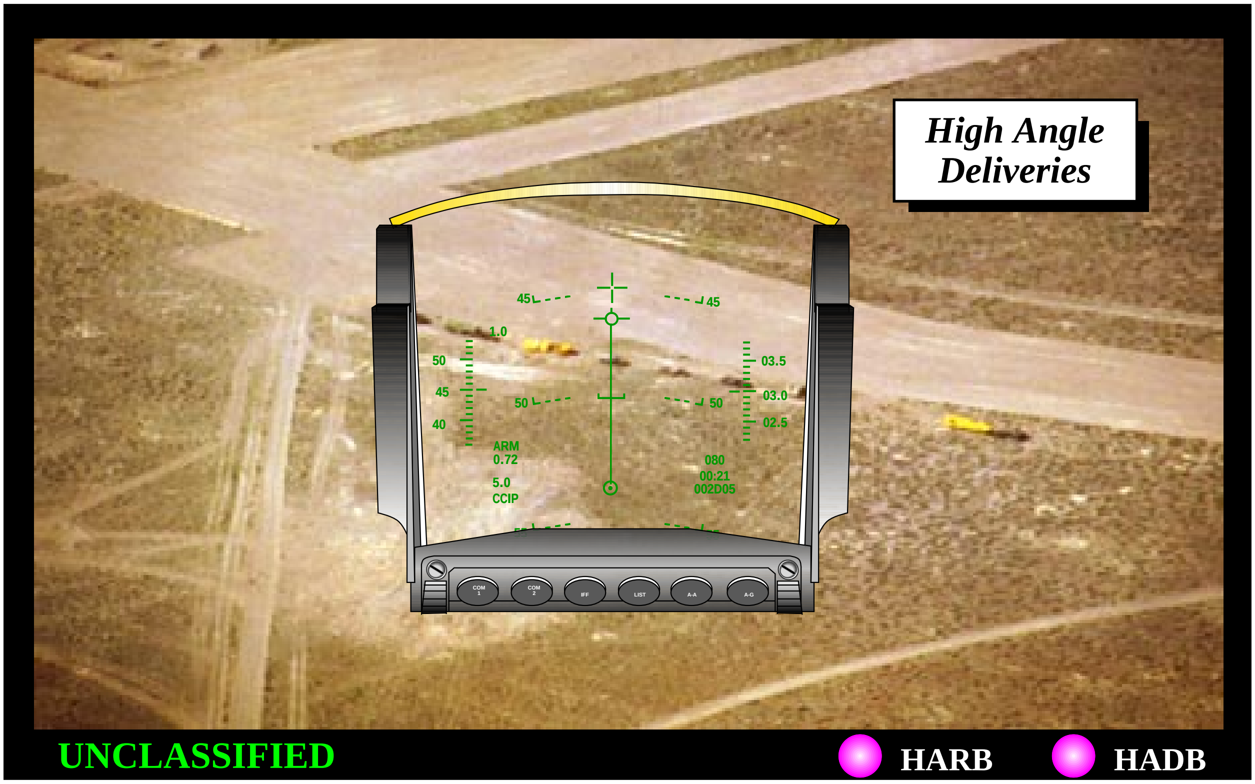
5.8.3.2. Disadvantages:

5.8.3.2.1. Increased exposure to certain surface-to-air missiles (SAM) and air-to-air threats.

5.8.3.2.2. Unpredictable weapons effects.

5.8.3.2.3. Decreased accuracy with free-fall munitions; especially CBU.

Figure 5.19. High Angle Deliveries.



5.8.4. Low-Altitude Toss. The low-altitude toss (LAT) profile allows accurate visual deliveries of low drag munitions at standoff ranges.

5.8.4.1. Advantages:

5.8.4.1.1. Provides lateral spacing for frag deconfliction.

5.8.4.1.2. Allows standoff from several lethal defensive systems.

5.8.4.1.3. Increased defensive maneuvering time against SAMs in the target area.

5.8.4.1.4. Allows considerable flexibility in meeting planned parameters.

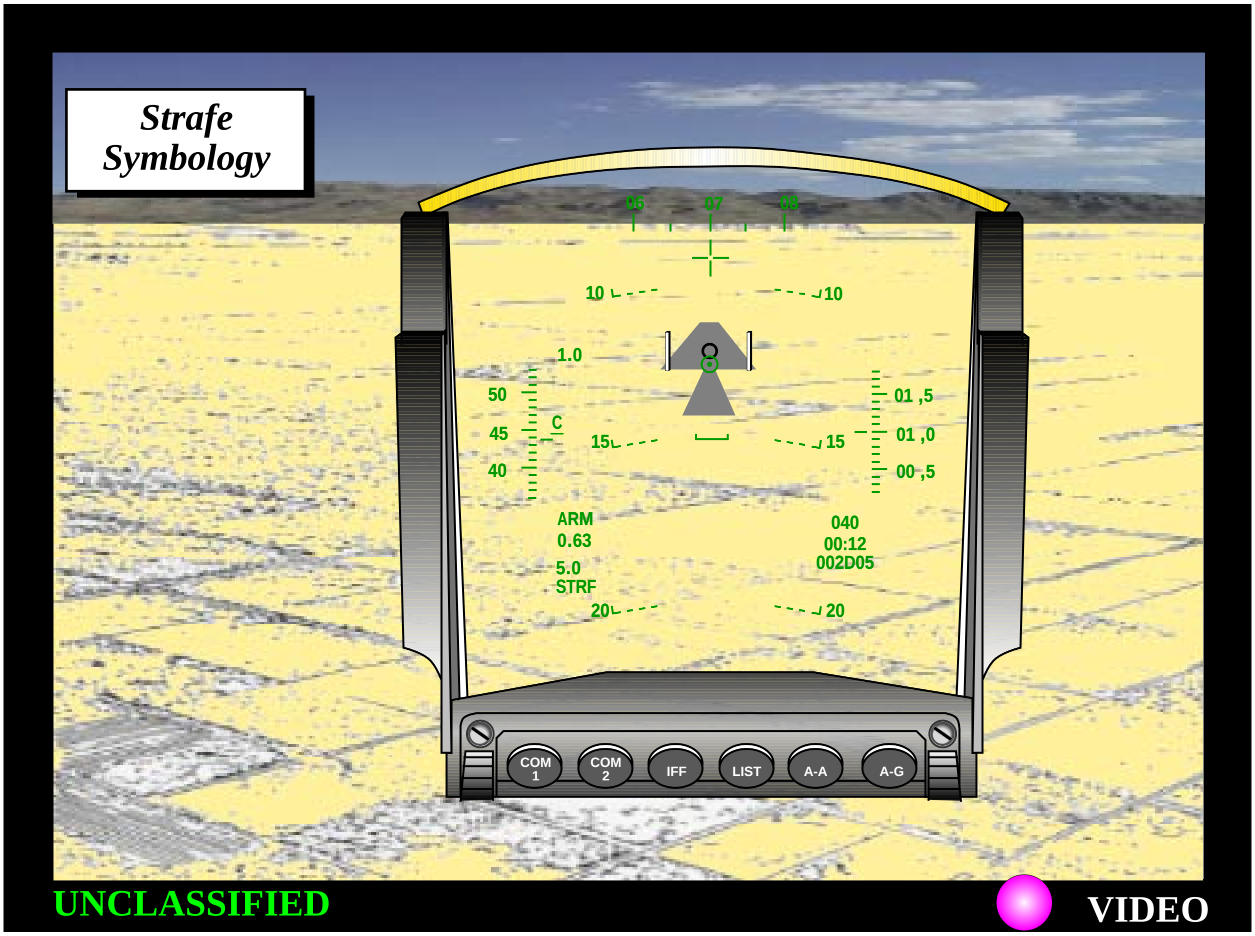
5.8.4.2. Disadvantages:

5.8.4.2.1. Accuracy is degraded over a CCIP delivery.

5.8.4.2.2. Long slant ranges can cause difficulties with target acquisition.

5.9. Strafe. Since the FCC merely presents a continuous prediction of bullet impact in the HUD, the fundamental techniques of manual strafe must still be applied. The primary advantages of computed strafe over manual strafe are the automatic calculation of an upwind aimpoint and the freedom to fire at any range within the effective gun envelope. These features permit reliable impacts even in high or changing crosswinds. (See **Figure 5.20.**, Strafe Symbology.)

Figure 5.20. Strafe Symbology.

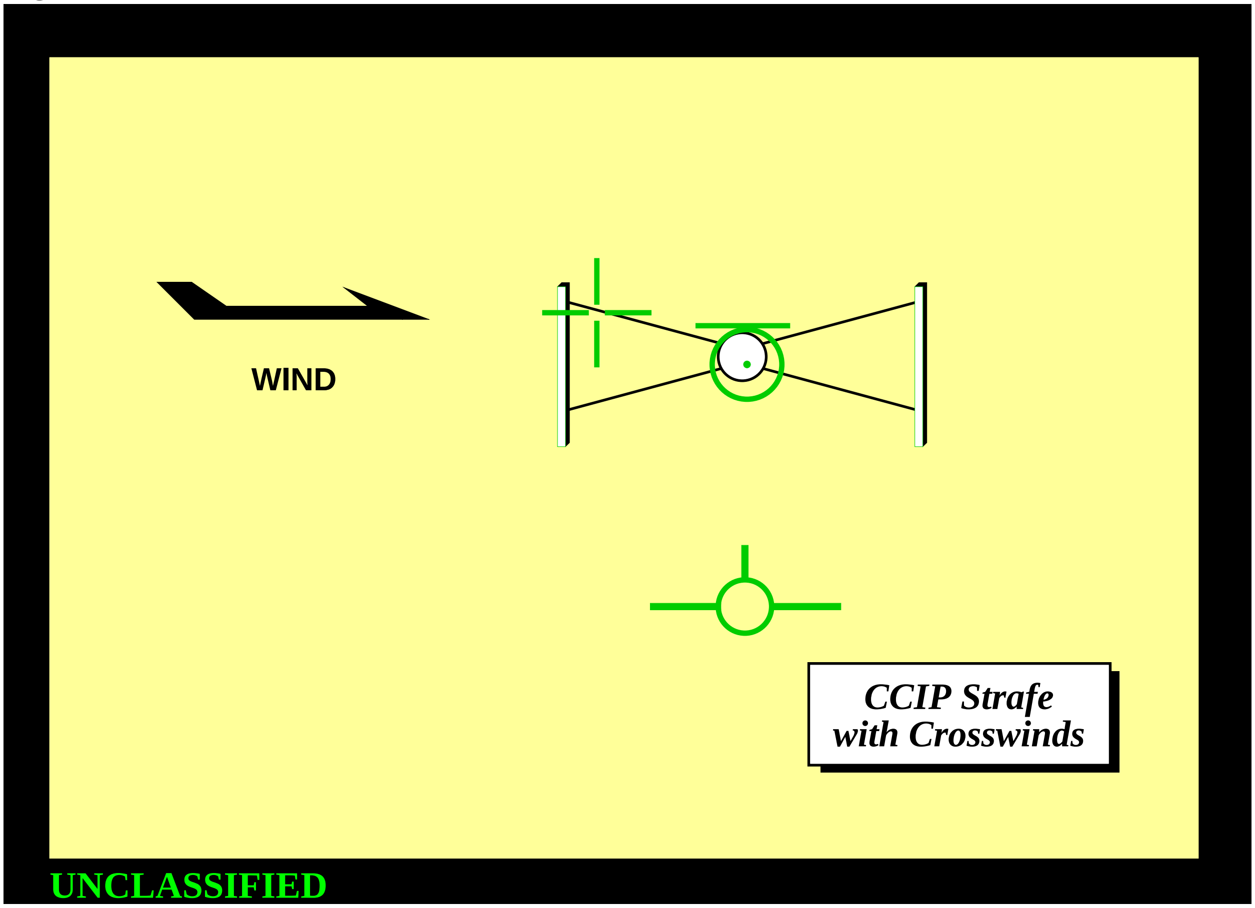


5.9.1. Effects of Wind. Winds are easily compensated for during CCIP Strafe.

5.9.1.1. Initial Aiming. When crosswinds are present, the FPM is shifted slightly downwind. The gun is still boresighted through the gun cross. Bullet impact will be someplace between the two, proportional to drift angle and slant range. Consequently, the aiming symbol will be upwind of the FPM. As the slant range decreases, the CCIP pipper will move laterally toward the gun cross. The combination of the two characteristics results in CCIP pipper motion, as range decreases from the original position, always toward the gun cross. Bank and/or yaw can distort this classic geometry slightly when maneuvering toward the target, but should not be a factor when approaching open-fire ranges. (See **Figure 5.21..**, CCIP Strafe with Crosswinds.)

5.9.1.2. During Delivery. Crosswind effect during firing can best be controlled by using small amounts of bank to control lateral pipper drift during the approach. This should result in having the proper amount of bank on the aircraft at open-fire range. Maintain this bank while firing which should keep the pipper from moving off the target downwind. Effect on bullet impact due to firing in a bank is minimal. A rule of thumb is that 1 knot of crosswind will require slightly less than 1 degree of bank to counteract. Compensating for a crosswind is subtly different in strafing. In bombing, the objective is to crab or drift so the bomb ground track passes through the target. Because of the self-possessed velocity of the bullets, the bullet track will not be at all the same as the ground track of a crabbed or drifting aircraft. Consequently, in strafe we are primarily concerned with aiming the gun, not the aircraft velocity vector, toward the target.

Figure 5.21. CCIP Strafe with Crosswinds.



5.9.2. Low-Angle Computed Strafe. On downwind select gun mode and strafe option on the SMS. Check Master Arm switch to MASTER ARM and ARM in HUD (local restrictions permitting). Verify air-to-surface gun symbology and declutter the HUD as necessary.

5.9.2.1. Fly the base leg and roll in as described for the lower angle bomb patterns. One technique is to roll out with the bottom of the gun cross on the target.

5.9.2.2. Lead the roll in to final in order to line up on the run-in line (if applicable) of your target. Normally, on a controlled range, there will be at least two active panels which are scored acoustically (acousti-score). Due to the nature of acousti-score, bullets that pass over the microphone high or are subsonic, will not register as hits.

5.9.2.3. A common technique is to strafe alternate panels (i.e., if number one chooses panel one, then number two strafes panel two, number three strafes panel one, etc.). This allows time for the dust to clear on that panel from a previous pass.

5.9.2.4. Symbology. The CCIP pipper is originally depressed for the slant range at which you roll out on final. When arriving at approximately 4,000 feet, an in-range cue ("the hat") will appear. As the slant range decreases, the CCIP pipper will rise vertically, reflecting a reduced gun elevation requirement. Although you will have a valid pipper at maximum range, strafe accuracy will be greatly increased by getting closer to the target and holding open fire until inside, approximately 4,000 feet slant range.

5.9.2.5. Increasing Effectiveness. There are generally two techniques used by pilots to achieve maximum LAS hits:

5.9.2.5.1. Option 1: Tracking the Gun Cross. Roll out with the gun cross slightly above the rag. Check dive angle at 10 to 15 degrees.

5.9.2.5.1.1. Note the pipper relationship to the run-in line to determine crosswind.

5.9.2.5.1.2. Offset gun cross into the wind and note pipper tracking up the run-in line.

5.9.2.5.1.3. Set power to maintain 420 to 450 KCAS.

5.9.2.5.1.4. At the point where the pipper track approaches the target, ease the pipper to the bottom of the rag.

5.9.2.5.1.5. As the 2,000 feet foul line passes under nose, track and hold CCIP pipper on rag.

5.9.2.5.1.6. Shoot.

5.9.2.5.1.7. Track rag momentarily (until either bullet impact or approaching the foul line).

5.9.2.5.1.8. Recover.

5.9.2.5.2. Option 2: Tracking Pipper. The second technique is to simply roll out on final with the pipper on the rag, cross-check the dive angle at 10 to 15 degrees, and just keep the pipper on the rag until the 2,000 feet foul line passes under the nose. Track, shoot, track, and recover from that point.

5.9.2.6. Sighter Burst. Regardless of the tracking method you use, it is still a good idea to fire a short (20- to 30-round) sighter burst on the first hot pass. Note the CCIP pipper position when you fire. If the impacts were not through the CCIP pipper, use an adjusted aimpoint on subsequent passes. On each pass ammunition is wasted if firing when CCIP pipper is off the aimpoint. Remember, ***Track, Shoot, Track***.

5.9.3. High-Angle Computed Strafe. This delivery is used much more frequently than low-angle strafe during tactical scenarios to avoid small arms fire and allow bullet penetration into revetted or entrenched positions. Open-fire slant range is typically more than twice that of low-angle strafe based on computed delivery. Consequently, computed impact prediction greatly improves results in an environment of unknown winds and extreme slant range.

5.9.3.1. Initial Picture. Perform the roll in from computed altitude as you would for a diving delivery with point-blank aiming. The FPM should initially be short of the target with the CCIP pipper some 50 plus mils below it. This roll in is significantly more nose-low than it is for a diving delivery because AOD is actually a negative value (short of the target). Using the gun cross as an initial aiming reference will help until the FPM and CCIP pipper become stabilized.

5.9.3.2. Final Attack. Note altitude and set power for release airspeed at open-fire range/ altitude. Monitor your descent rate toward open-fire altitude. Control the rate of CCIP pipper movement toward the target with back stick and bank so as to have it at the target as you arrive at desired open-fire altitude. Since the in-range cue does not appear until 4,000 feet (for M56) slant range, it may not be above the CCIP pipper at open-fire range/altitude. Recovery can be based on slant range, altitude, or a combination of both.

5.9.4. Manual Low-Angle Strafe. Compared to bombing, strafe attacks are relatively simple. Point the aircraft at the target, correct for gravity drop, include a small amount of wind correction, and fire.

5.9.4.1. Downwind. On downwind, check sight depression mil setting (usually 6 to 10 mils) and adjust manual reticle intensity low enough to allow you to see and focus on the target.

5.9.4.2. Transition to Final. Fly base and roll in similar to low angle bomb patterns. Before you roll in, look at the target and pinpoint the general location of the open-fire range. On controlled ranges, this is approximately 150 percent of the distance from the foul line to the target.

5.9.4.2.1. Roll-In. During roll-in, keep your eyes primarily on the target/aimpoint with an occasional cross-check of airspeed. As the target comes into the HUD field of view (FOV), play the roll out so that the pipper is initially short and slightly upwind of the target/aimpoint. In practice, it is advisable to plan the final turn to roll out with the pipper slightly upwind (laterally) of the target/aimpoint. A crosswind component will require the gun to be pointed upwind 1.5 feet per knot at 2,400 feet open-fire range, decreasing to 1 feet per knot at 2,000 feet.

5.9.4.2.2. Final Attack. After roll out and IPP, check airspeed and adjust power. Recheck and readjust as required. Airspeed has little effect on bullet impact, but it does effect aircraft control. As you close toward the target, focus your eyes on the chosen aimpoint and monitor pipper movement with your peripheral vision. The pipper should be moving smoothly towards the aimpoint:

- Continuously estimate your closure rate toward the open-fire range.
- Use bank to adjust lateral pipper movement.
- Longitudinal (6/12 o'clock) drift rates are critical and more difficult to correct.

5.9.4.3. Firing the Gun. You want to open fire with the pipper on the aimpoint when you are approximately 3,000 feet from the target. Open fire range is more critical in manual strafe, as bullet drop increases dramatically as firing range increases. During the firing of the gun, the pipper must be on the aimpoint. About 2 seconds of tracking is the maximum you will be able to achieve. Therefore, do not concentrate tracking the pipper on the aimpoint before open-fire range. Fire the gun using just enough forward stick pressure so the pipper “pauses” on the target between open fire and cease fire. On the first strafe pass you may want to fire only a “sighter burst.” The purpose is to verify gun/pipper boresight and validate your crosswind computation. Cease fire as you approach the foul line and initiate a recovery.

5.9.4.4. Manual High-Angle Strafe. This delivery is difficult in that release parameters are near the outer limits of effective 20mm gun range. In a 30-degree attack, a typical open fire slant range is 6,000 feet which requires considerable gun elevation to counter the increase in gravity drop. Since the path of the bullets is no longer flat, open-fire slant range becomes more critical. As you reach 1,000 feet above open-fire altitude, move the pipper up to the aimpoint. Track, fire, and track until the burst is completed. Execute the recovery immediately after the gun stops firing. Do not delay to watch bullet impact. Due to the increased range and corresponding increased bullet TOF, if you see the impact, you may never see anything else, other than your own impact.

5.10. Tape Assessment and Foot Print Data. The squadron should have foot print data for all its aircraft. The validity of data is based on each pilot properly assessing their performance on each pass and comparing aimpoints to impacts. The program is only as good as the inputs, so VTR assessment and accurate bomb sheets are essential. Before you fly, look at the foot print data. Do not aim 50 feet short just because the last pilot wrote that your aircraft had dropped 50 feet long. See how recent the last flight was and look at the last pilot's experience level. ***NOTE***: An intelligent AF Form 781 write up goes a long way, but frequently, impact errors are caused by bad boresight, a problem that cannot be corrected overnight.

5.11. Non-Visual Bombing. This section covers delivery modes (CCRP, LADD, VIP, and BCN) you can use to accurately attack targets without visually seeing them. The most obvious use of non-visual capability is in weather or at night. There are, however, day visual meteorological condition (VMC) tactical situations where target exposure may be reduced with accurate target coordinates as in a low-altitude loft option. Use non-visual techniques (rolling in on CCRP data) to help find the target and then convert to a pure visual attack (CCIP or DTOS). If navigating to a target and bombing it solely using the INS, accuracy will be limited by planning errors and/or INS drift. Accuracy can be improved by updating the FCC with radar, HUD, and/or overfly-designate updates. A combination of GPS and accurate coordinates is the best solution. INS updates may also improve delivery accuracy. Even when the target area can be seen, using the TD box in conjunction with visual search lessens the possibility of DMPI confusion due to passive camouflage, concealment, deception (CCD) techniques. For example, the TD box may designate a target that has been toned down with nets or paint, leaving an intentionally developed false target nearby to draw the attention of the attacker. An effective practice is to closely examine the TD box in CCRP or target diamond in CCIP before consenting weapons release.

5.11.1. Loft Tactical Considerations. The loft delivery is usable for area targets when using area weapons or when standoff is required against short-range defenses. Accurate coordinates and verified system accuracy (INS, FCC, system altitude) are paramount to ensure desired weapon effects. Azimuth steering and the initial pull-up are the most critical factors in this maneuver. The FCC will still attempt to deliver the munition to the correct point over the target, but variations become important with radar-fuzed munitions and special weapons.

5.11.1.1. Advantages:

- Weapon delivery takes place at standoff ranges of 2 to 5 NM from the target.
- Radar-fuzed CBU munitions can be delivered from low run-in altitude.

5.11.1.2. Disadvantages:

- The aircraft is exposed belly-up to the target area and the loft maneuver may place the aircraft in SAM engagement zones.
- Accuracy is decreased with INS navigation errors (especially non-GPS aircraft).
- Long weapon TOF combined with wind effects results in decreased accuracy.
- Accurate target and aiming offset coordinates must be available.

5.11.2. Critical Avionics. The APG-66 radar, FCC, and other F-16C system integration areas combine the primary components to accurately employ ordnance on a non-visual target. The FCC uses INS information to position HUD and radar symbology on the selected reference. The pilot can update symbology by inputting FCC slew commands or by designating the visual reference point (VRP) to the FCC at overflight (VRP/computed release point [CRP] mode). Overall system accuracy is a function of input data, INS drift, NAV status, and any updates made by the pilot.

5.11.2.1. APG-66 Radar. The FCC places the radar cursors at the INS estimated position of the steerpoint or OAP. Refinements can be made using the cursor on the throttle. For more detail, depress the RETURN-TO-SEARCH switch to get to the EXPAND mode. This places the cursor in the center of the display and expands the detail by a factor of four. In 10, 20, and 40 NM scopes depressing the RETURN-TO-SEARCH switch again commands the DBS mode, which increases azimuth resolution for returns more than 15 degrees off the nose.

5.11.2.2. Elevation Strobe. Antenna elevation, or tilt, is controlled by the FCC in GM to keep the radar pointed at the steerpoint or OAP. Override the FCC by moving the antenna elevation thumbwheel out of the detent. The FCC will still automatically adjust tilt but it will be biased by the elevation knob position.

5.11.2.3. Range. To get the best resolution, you should use the smallest range scale that will allow you to see the cursors.

5.11.3. Fire Control Computer Data. Accurate steering is obviously driven by the accuracy of the data entered. The VRP bearing and range data must be correct, and both points must have accurate elevations entered. Elevations are important since this data is used for positioning radar and HUD symbology. Additionally, anytime you bomb with the FCR in a non-AGR mode, the FCC uses steerpoint elevations for BARO bomb computations.

5.11.4. System Integration. There are several release options to choose from on non-visual attacks. CCRP provides good flexibility, providing adequate references to drop from medium or low altitude, from a level, dive, or climbing (lofted) delivery. If a loft delivery is desired, and a precise loft release angle is required, LADD mode is the best option. Both GM radar and/or Visual Reference Point (VRP) slews/designates may be used with the LADD or CCRP modes to refine the FCC release solution. Visual Initial Point (VIP) mode provides steering to a target from a known INS steerpoint. VIP is useful for close air support (CAS) scenarios when non-preplanned targets must be struck, but preplanned initial points (IP) are known to the forward air controller (FAC). Beacon mode is considered a specialized delivery option and is not addressed in this document. Reference the Dash-34 for Beacon specifics.

5.11.4.1. Symbology. When you select CCRP or LADD delivery mode on the SMS, the IP or TGT steerpoint must be selected on the FCNP and VRP/VIP must have been previously mode selected for the VRP/VIP sighting options to function. Only one mode, VRP or VIP, can be selected at a time. With these requirements met, the radar cursors automatically go to the target, OAP, or IP/RP (depending on what rotary/sighting option selected). The HUD symbology, TD box, OAP triangle, and the IP/RP diamond appear if these points are in the HUD FOV. If the TD box is not in the HUD, the pilot will see the target locator line (TLL).

5.11.4.2. Slew Inputs. If an aiming error is discovered, slew the cursors or HUD symbology over the point of interest. All cursor slews carry over for other steerpoints and deliveries. Cursor zero (CZ) can be used to clear all slews and place the cursor at the INS estimated point. The bearing pointer and distance measuring equipment (DME) on the horizontal situation indicator (HSI) points to the INS estimate of the steerpoint.

5.11.5. Continuously Computed Release Point and Visual Initial Point/ Visual Release Point Computed Release Point Specifics.

5.11.5.1. Radar Slewing. The use of the OAP helps develop a pointing system to make target identification easier. Selecting an OAP as a sighting reference will cause the radar cursors to move from the steerpoint to the selected offset point. Check the location of the OAP prior to going to expand to ensure that the cursors move to the correct position. In expand, the cursors are set at half-scope range and OAP selection will shift the map display rather than the cursors. Ensure the radar return chosen to slew on corresponds to the selected aiming reference (i.e., OAP 1 or OAP 2). Whether DIR, OAP 1, or OAP 2 is selected, HUD steering is always to the target, and adjusted for FCC inputs. Anytime a significant error is made with an FCC slew input or if the scope relationships just do not appear to be correct, you can return to raw INS data by depressing the CZ Option under MISC on the FCNP data knob.

5.11.5.2. Visual Reference Point (VRP). The VRP option is available anytime CCRP or LADD are selected as the delivery mode and valid VRP data entered from the target to the visual point. While OAP provides a method of updating radar sighting to a target, VRP provides a visual means of doing the same thing. Once VRP data has been entered, the HUD will display a small circle at the programmed bearing and range for the VRP. The HUD symbology can be slewed over the point using cursor inputs and/or the pilot can overfly the point and designate to update the FCC steering.

5.11.5.3. Visual Initial Point (VIP). Is useful when target position is known relative to a specified initial point (IP) which has been entered into the FCC. Target data are entered as bearing, range, and elevation relative to the planned IP. These data may either be pre-computed, or received real-time as part of a re-tasking or close air support (CAS) scenario. Reference the dash-34 for specifics on VIP symbology. VIP functions much like CCRP or mode with VRP data entered, with three primary differences.

5.11.5.3.1. The first difference is that unlike VCRP or VLAD, VIP cursor designate inputs are not dumped by DGFT or MSL OVRD selection. This provides increased flexibility to react to air threats while retaining the updated VIP steering solution. If VIP mode is deselected via the SMS, VIP designates are dumped.

5.11.5.3.2. The second difference is that after designating over the VIP point, a second designate command puts the FCC into a mode that is functionally identical to DTOS. VCRP/VLAD lack this feature, although DTOS is available hands-on through the NWS button in these modes.

5.11.5.3.3. The final difference is that under the normal method of using VIP (overflying an IP loaded as an FCC thumbwheel, and then going to the target) the HSI bearing pointer continues to point at the thumbwheel destination following VIP slew/designation. Under the normal employment of VCRP/VLAD, the target is an FCC thumbwheel, and the bearing pointer always points toward the target. Most pilots prefer having the HIS point to the target for SA and re-attack purposes.

- VIP/VRP mode—mode select on DED/set proper steerpoint as IP/target, if desired.
- Master mode—A/G.
- Steerpoint selected—TGT (IP for VIP mode).
- FCR mode—GM, SEA, BCN, GMT.
- SMS—weapon, profile, RP, pair/SGL, CCRP, release angle (if appropriate).
- Master Arm switch—MASTER ARM or SIMULATE.
- Sight point option—select TGT/OA1/OA2/IP/RP.

5.11.5.4. Employment Considerations:

5.11.5.4.1. Ranging is BARO since AGR is unavailable. Check system altitude and do an ACAL if required.

5.11.5.4.2. Check the antenna elevation knob in the detent. The FCC will automatically control tilt.

5.11.5.4.3. Work big to small. Select the best radar return—DIR/OA1/OA2. Adjust radar gain to eliminate background clutter, if required, using hands-on control.

5.11.5.4.4. Once the proper return has been positively identified, Expand and DBS may be used to refine cursor placement.

5.11.5.4.5. If a visual overfly update is desired, depressing designate will update the weapons aiming solution. Further refinements can be made on the radar if required.

5.11.5.4.6. Fly the FPM to the steering line or center the steering symbol on the radar or SMS. Time to release is available in the HUD.

5.11.5.4.7. A 100-milliradian circle appears in the HUD to warn of the maximum solution, 2 seconds prior to maximum range for weapon delivery. At maximum solution range, the circle flashes for 2 seconds, then disappears and the solution cue appears on the BFL.

5.11.5.4.8. CCRP allows you a choice of delivery G and pitch. You can pull up and loft the ordnance, continue in level flight, or dive at the target if required.

5.11.5.4.9. When the solution cue reaches the FPM, the bombs will release and the FPM will FLASH.

5.11.5.4.10. The SMS weapons quantity will not count down until the pickle button is released. If the weapon quantity decreases to zero, the HUD A/G symbology will disappear.

5.11.6. Low-Altitude Drogue Delivery and Visual Initial Point/Visual Reference Point Low-Altitude Drogue Delivery. The low-altitude drogue delivery (LADD) mode was originally designed for delivery of retarded weapons with an airburst fuzing requirement.

5.11.6.1. System Use. Currently the LADD is most often used to loft free-fall airburst type weapons. Actual weapons release computations in the FCC are very similar to CCRP with a few notable exceptions. The LADD mode replaces the maximum range CCRP solution with a programmed 4-G pull to a 45-degree climb angle. This pull-up maneuver occurs at a pilot entered pull-up range. The LADD mode allows the pilot to enter a LADD TOF which enables the FCC to compute and compensate for average wind effect on the bomb after release. With a value other than zero entered in LADD TOF, the FCC will adjust the programmed pull-up range for variations in GS. Switches:

- VIP/VRP sighting option—mode select on DED, set proper steerpoint as IP/target.
- Master mode—A/G.
- Steerpoint selected—TGT (IP for VIP mode).
- FCR mode—GM, SEA, BCN, GMT.
- SMS—weapon, profile, RP, pair/SGL, LADD.
- SMS control page—pull-up range, verify.
- Master Arm switch—ARM/SIMULATE.
- Sighting point—TGT/OA1/OA2/IP/RP.

5.11.6.2. Employment Considerations.

5.11.6.2.1. Radar operation, consideration, and procedures are the same as those for VIP/VRPCRP.

5.11.6.2.2. Vertical steering cue appears and moves toward the FPM, 10 seconds prior to pull-up.

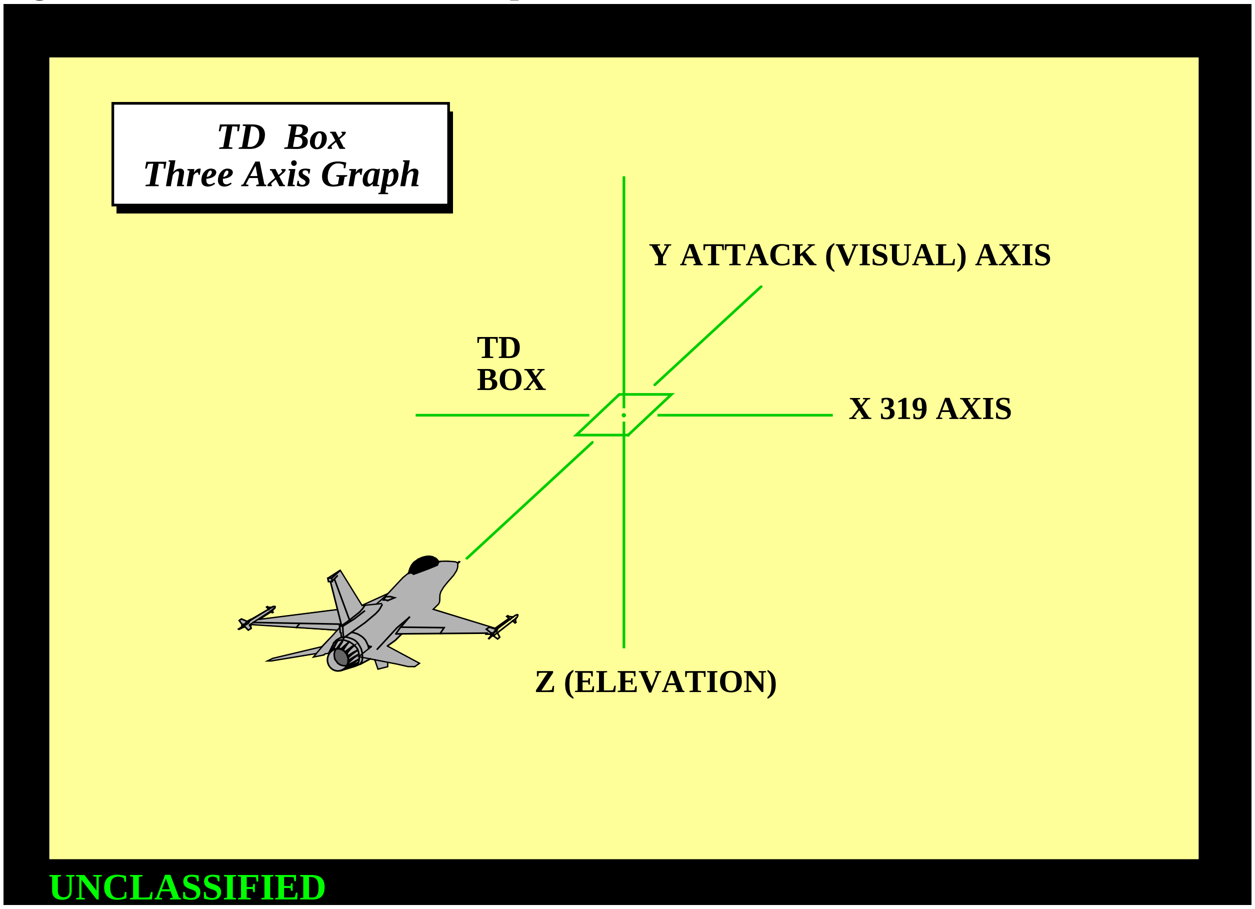
5.11.6.2.3. When the cue hits the FPM the solution cue resets to the top of the HUD and this vertical steering cue commands a pull to 45 degrees.

5.12. System Altitude Errors. Unknown or uncorrected system altitude errors have a negative impact on the accuracy of the F-16's computed weapons deliveries (non-AGR). A comprehensive understanding of factors effecting TD box placement, the impact a system altitude error has on delivery accuracy, and methods to correct system altitude errors is required to effectively employ the F-16.

5.12.1. Factors Effecting Target Designator Box Placement. There are many factors that effect TD box placement. Target coordinates and elevation data as extracted from reference charts must be as precise as possible. The data extracted from a 1:500,000 is less accurate than from a 1:50,000 chart. A second factor effecting TD box placement is the accuracy of initial INS alignment. Get the system as accurate as possible. Do not accept a second-rate INS. The final factor effecting TD box placement is the accuracy of INS estimates of present position and FCC (with INS input) estimates of current system altitude. The avionics system assumes its estimates of present position and system altitude are correct and then proceeds outward to the target position to display symbology. Therefore, if the estimates of present position and system altitude are incorrect, the display of target symbology will also be incorrect.

5.12.2. Target Designator Box Placement with Errors. The placement of the TD box is on a three-axis graph as shown in **Figure 5.22.**, TD Box Three-Axis Graph. The X-axis (3/9) of the graph represents side to side or latitude (N-S), the Y axis represents aircraft heading or longitude (E-W), and the Z axis represents elevation of the target. The TD box will not be on the target, if any one of these values is erroneous. As shown in **Figure 5.23.**, TD Box Error, an incorrect elevation value and/or system altitude error effects TD box placement along the Z axis. The TD box appears long of the target if the elevation entered is higher than actual or the system altitude is low. The TD box appears to be short of the target if the elevation entered is lower than actual or the system altitude is high.

Figure 5.22. TD Box Three-Axis Graph.

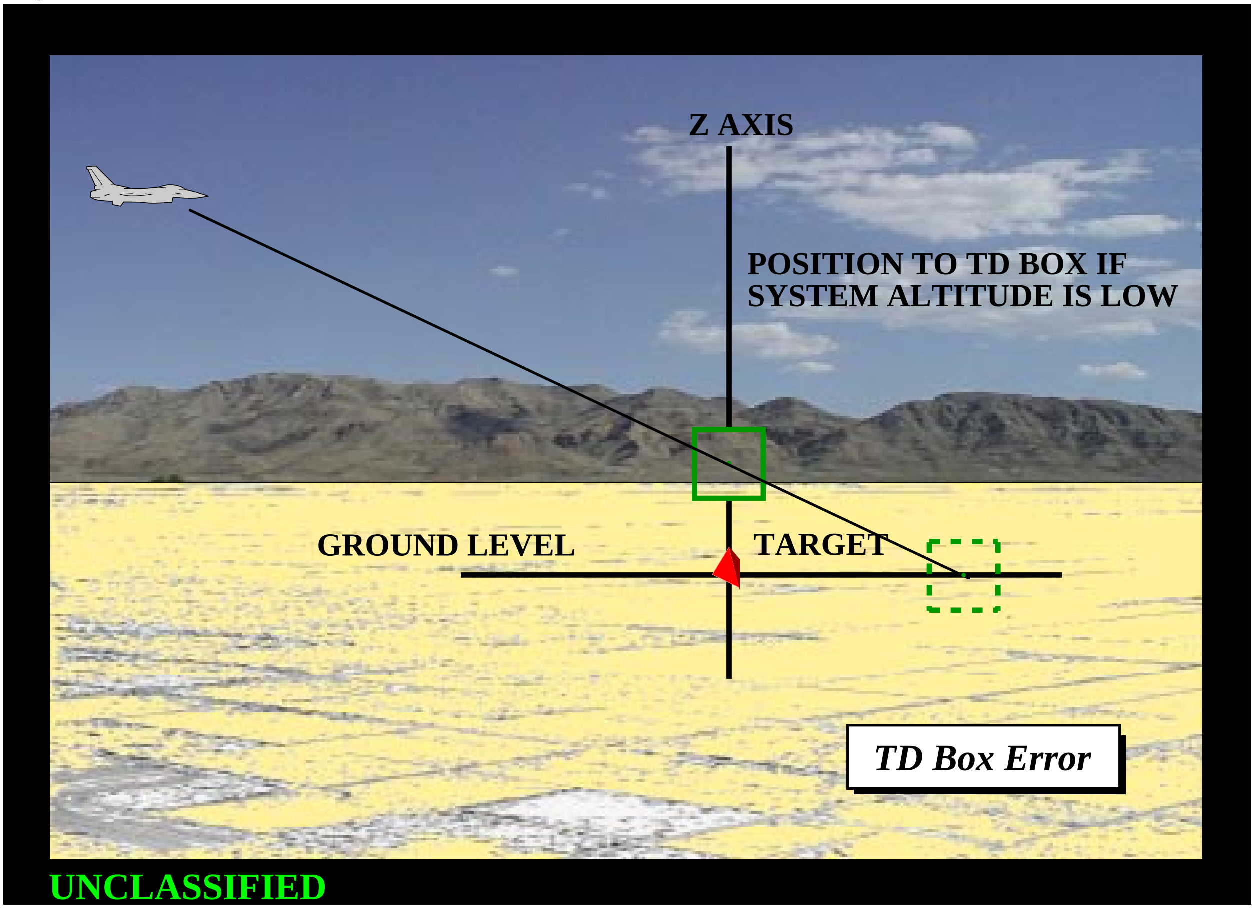


5.12.2.1. System Altitude–Low. System altitude is low when the TD box appears to be positioned long of the target and its actual position on the three-axis graph is high of the target. An example is shown in **Figure 5.24.,** System Altitude—Low. Approaching the target/steerpoint the actual position of the TD box remains constant. The position of the TD box appears to track to a point under and behind the aircraft, but toward the target in a time-sequenced profile view.

5.12.2.2. System altitude–High. The opposite is true when system altitude is high. An example is shown in **Figure 5.25.,** System Altitude—High.

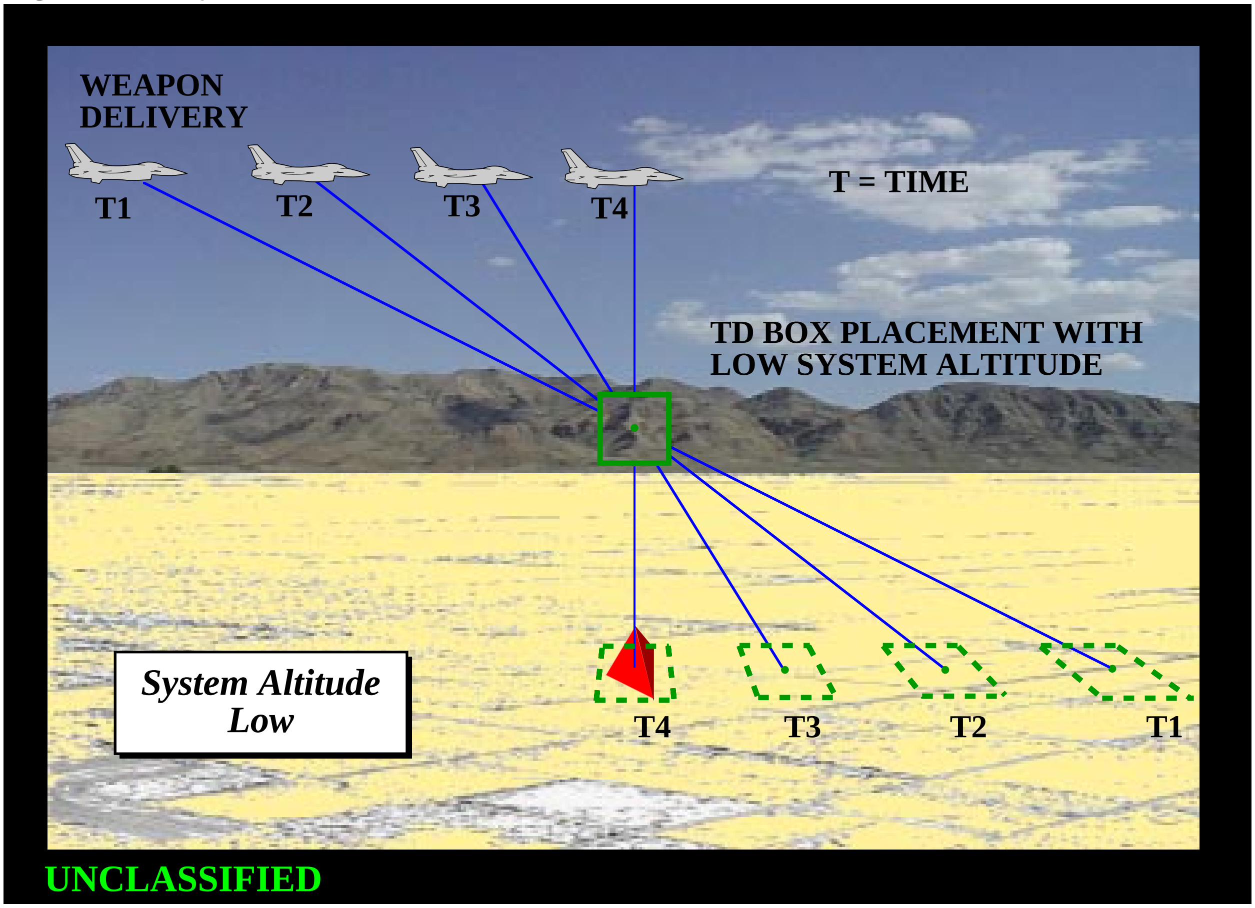
5.12.2.3. System Altitude–Accuracy (Blind). System altitude errors definitely effect weapon delivery accuracy. A review of blind delivery events and visual delivery events is required to understand weapon delivery errors due to incorrect system altitude. In a blind delivery event, assume the radar cursors are correctly positioned on the aimpoint, and the TD box location is ignored.

Figure 5.23. TD Box Error.



5.12.2.3.1. A low system altitude results in a long impact because the FCC thinks the target is above the actual elevation and computes a late release (low system altitude equals a long bomb). (See **Figure 5.24.**, System Altitude—Low.)

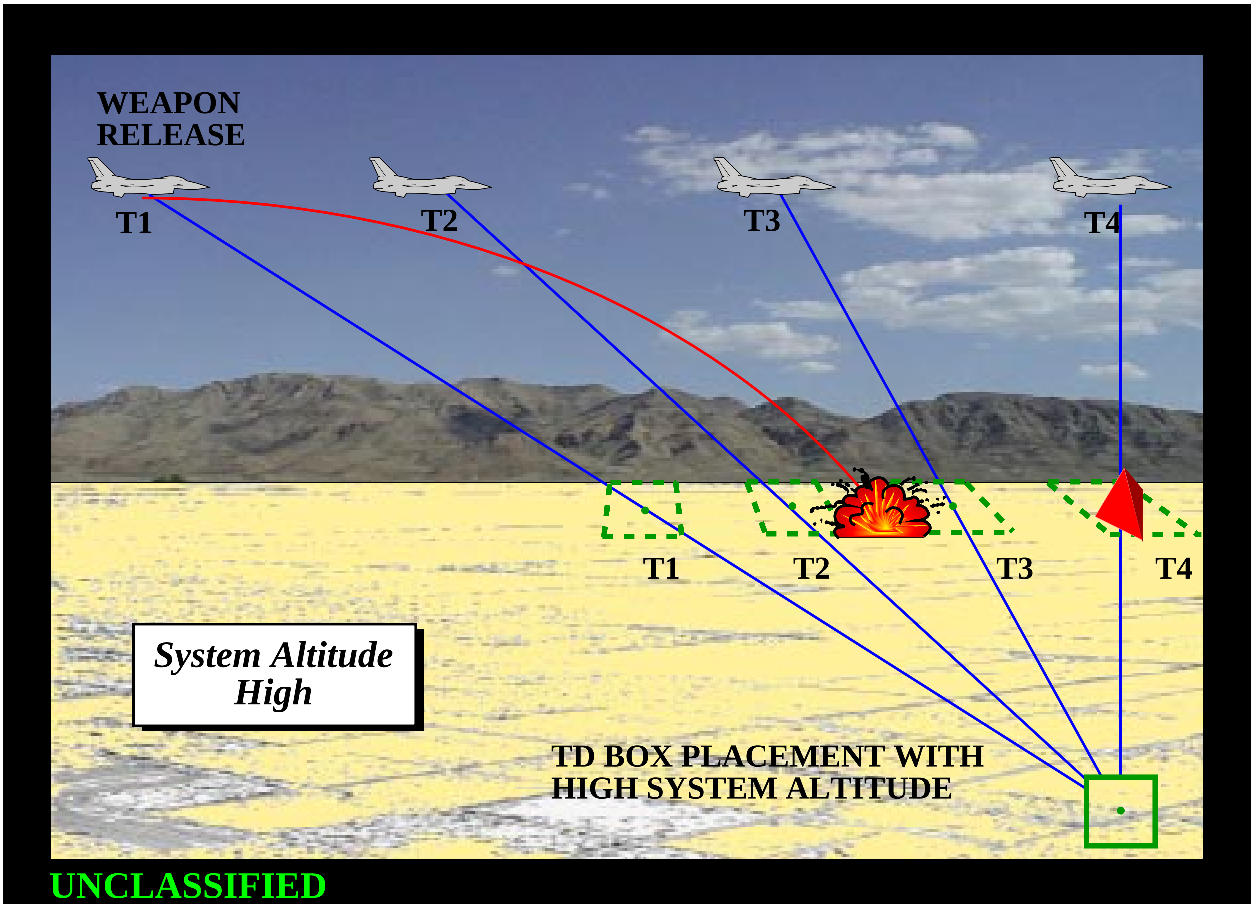
Figure 5.24. System Altitude—Low.



5.12.2.3.2. If system altitude is high, a short impact occurs because the FCC thinks the target is below the actual elevation and computes an early release. The TD box appears short of the target and the system tries to drop the weapon through the TD box. However, bomb impact error will be less than TD box positioning error. (See **Figure 5.25.**, System Altitude—High.)

5.12.2.4. System Altitude—Accuracy (Visual). Impact errors due to system altitude inaccuracy in visual deliveries are opposite those experienced in blind deliveries. Visual events such as DTOS employ sighting through the HUD. TD box location is set via the HUD LOS and ignores radar cursor placement. The same errors occur in CCRP if 6 to 12 o'clock TD box errors are corrected using the HUD as a reference.

Figure 5.25. System Altitude—High.

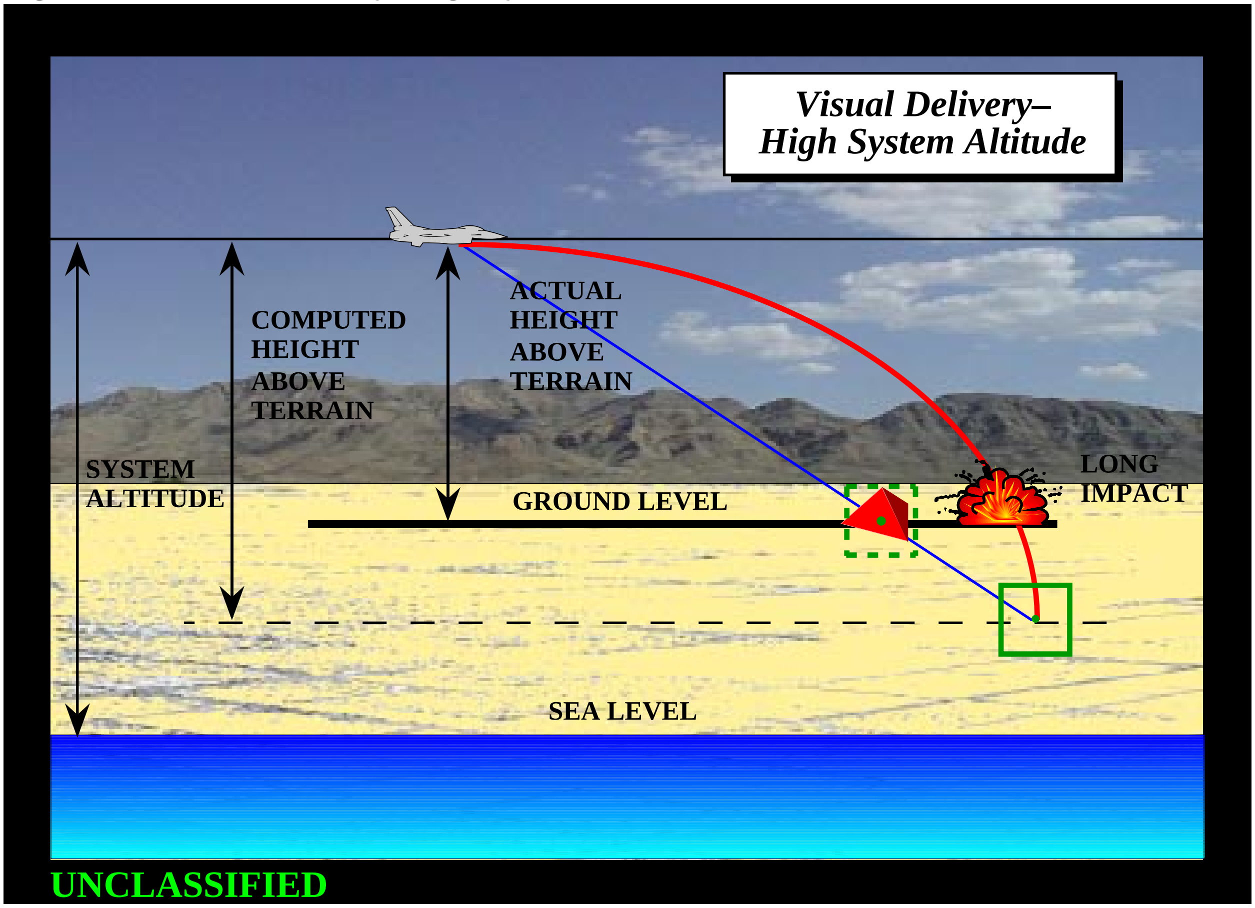


5.12.2.4.1. Even with the TD box on the target, if system altitude is high, the FCC thinks the target elevation is below actual and computes a later release point resulting in a long impact. (See **Figure 5.26.**, Visual Delivery—High System Altitude.)

5.12.2.4.2. If system altitude is low, the FCC thinks the target elevation is above the actual elevation and computes an early release point resulting in a short impact. (See **Figure 5.27.**, Visual Delivery—Low System Altitude.)

5.12.3. Correcting System Altitude Error. The best method to correct for a known system altitude error is to do an ACAL. There are a variety of methods which include radar altimeter (RALT), FCR, DVAL, etc. to update system altitude. Refer to the Dash 34 for the various ACAL update procedures. Target elevation, in lieu of an ACAL, can be adjusted to account for system altitude errors. Increase the target elevation, for a high system altitude, and decrease the target elevation for a low system altitude. The problem with this correction method is determining the magnitude of the elevation correction. It is a trial and error solution. A more realistic and the most often used method to correct for system altitude error is to aim short or long of the target when BARO bombing or select a delivery mode that uses AGR.

Figure 5.26. Visual Delivery--High System Altitude.

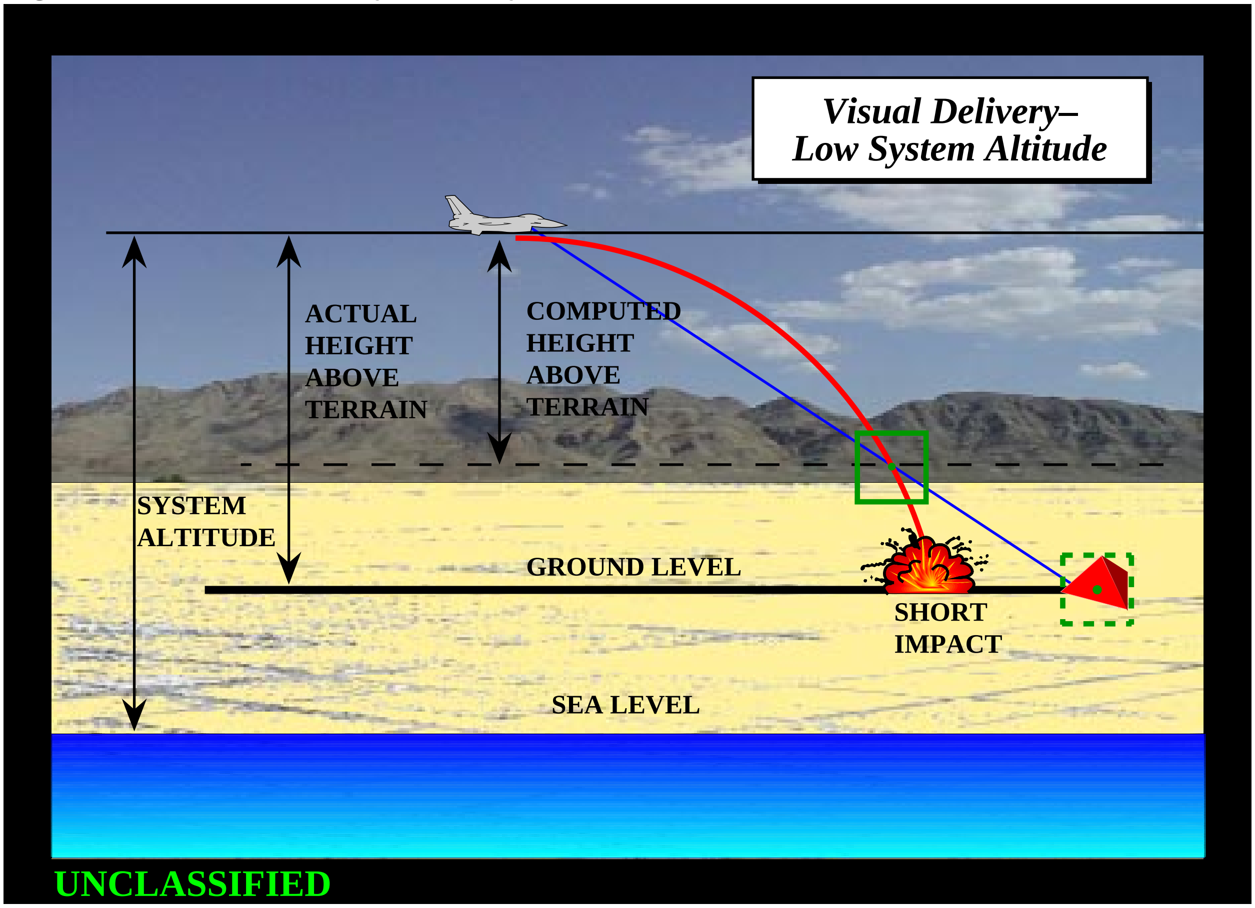


5.13. Controlled Range Patterns. Basic or initial qualification will normally be accomplished on a conventional manned range. (See **Figure 5.28.**, Conventional Range Pattern.) There are usually four patterns available to accomplish the various events: box, curvilinear, pop-up, and radar. Curvilinear and pop-up patterns are considered tactical deliveries.

5.13.1. The Box Pattern. The pattern activities described here will span approximately 80 to 90 seconds.

5.13.1.1. Crosswind. When turning crosswind (or any other place in the pattern), realize that you may be turning inside the preceding aircraft (the “coffin corner”). Roll out or ease off momentarily and look outside as well as inside your turn until you are sure your turn is clear. If you are still not sure who is where, ask! Example: “VIPER 1, SAY POSITION.” All other flight members should stay off the radio except to resolve the situation: “VIPER 1 IS TURNING BASE.” Once the visual is regained, or situational awareness (SA) confirms there is no conflict, the effected fighter should transmit “VIPER 2, CONTINUE.” If the situation can not be immediately resolved, a “KNOCK-IT-OFF” will be called. Maintain altitude separation until the confusion is resolved to avoid passing or colliding with the preceding aircraft. This will also aid in keeping the pattern from becoming uncomfortably tight.

Figure 5.27. Visual Delivery—Low System Altitude.



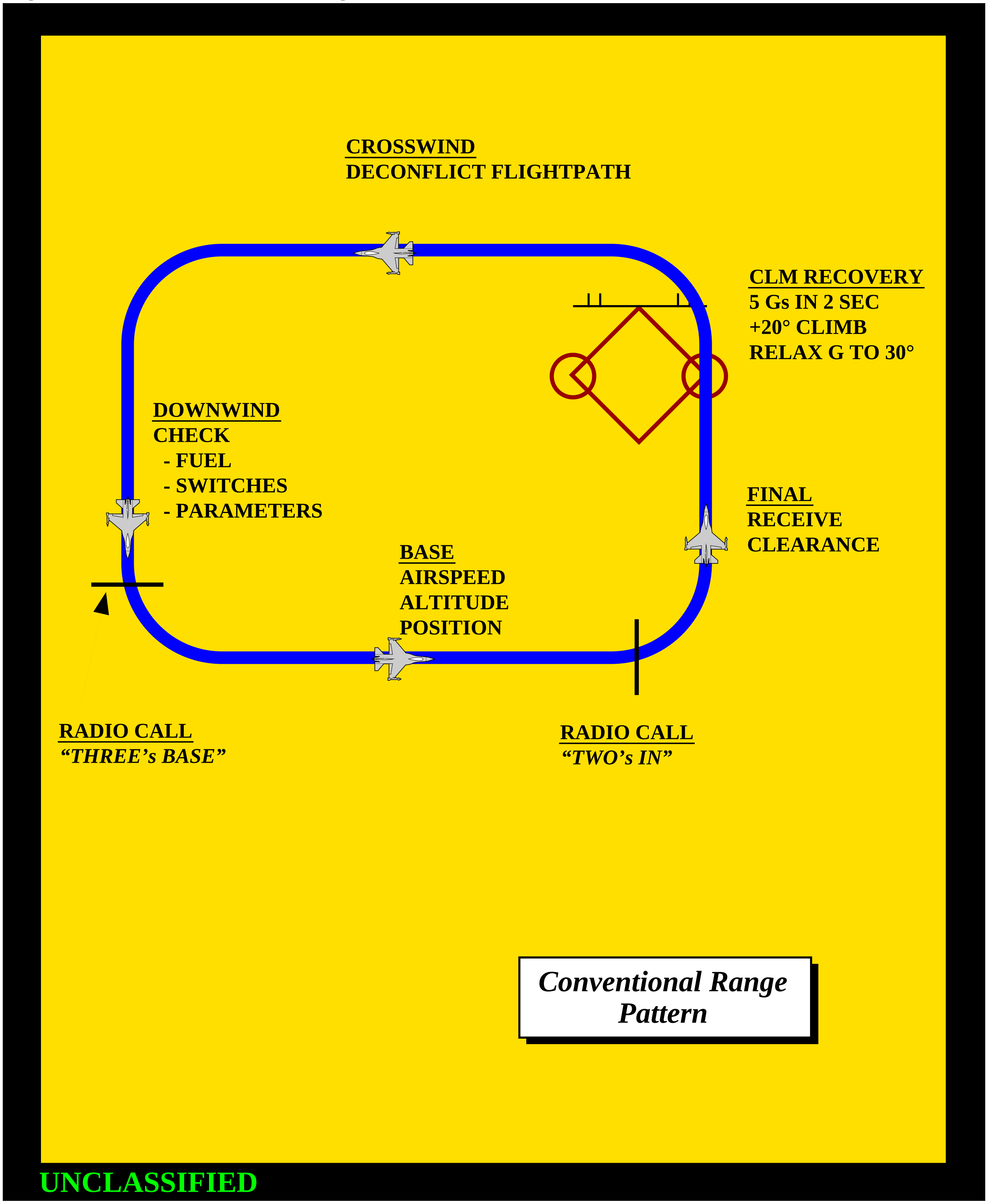
5.13.1.2. Downwind. The flight leader will establish the downwind leg ground track. This is not a fixed position and may be varied by individual pilots to adjust spacing. Downwind should be wide enough to allow for wings-level stabilization on the base leg.

5.13.1.2.1. In low-angle patterns (20 degrees or less), adhere closely to the pattern airspeeds and altitudes. In higher altitude delivery patterns, climb at an airspeed no slower than the planned base leg airspeed. Plan to arrive at base leg altitude prior to actually turning base. On hot days or with higher gross weights, afterburner may be required.

5.13.1.2.2. While on downwind prepare armament systems as necessary. Evaluate pattern spacing and analyze delivery errors. Analyze winds and adjust pattern as necessary to fly the correct ground track.

5.13.1.2.3. A four-ship is properly spaced when an aircraft is at each of the four corners of the pattern. Alter the distance abeam the target on downwind as necessary to adjust pattern spacing.

Figure 5.28. Conventional Range Pattern.



5.13.1.3. Base. Base position is one of the most critical positions in the pattern. It determines proper dive parameters and is normally the largest cause of poor parameters when improperly flown. There are three major conditions required to begin a successful roll in. Airspeed, altitude, and base distance. Determine these parameters through attack calculations done during preflight planning or a taken from locally approved weapons attack guides. The proper base distance can be achieved via two sources: eyeballs (visual point on the ground or visual assessment of the wire) or the HUD. The easiest way is to set the correct target-to-canopy reference or "sight picture" for the event being flown while on base. (See **Figure 5.29..**, Target Canopy References.)

5.13.1.3.1. Using HUD Data. With an accurate INS/FCC, the base position can also be flown by using the range calculations in the HUD (CCRP mode). This can be an accurate base distance used for not only a box/curve pattern, but also a pop-up and roll-in point for low- and high-altitude attacks. A practice of using CCRP with a preplanned roll-in range could enhance the attack parameters.

5.13.1.3.2. Procedures. The following procedures should be used when flying the conventional range pattern:

5.13.1.3.2.1. Do not vary base leg position to adjust pattern spacing. If you are too close behind the aircraft ahead, turn base at the normal point and plan to go through dry on final. Adjust your pattern on downwind.

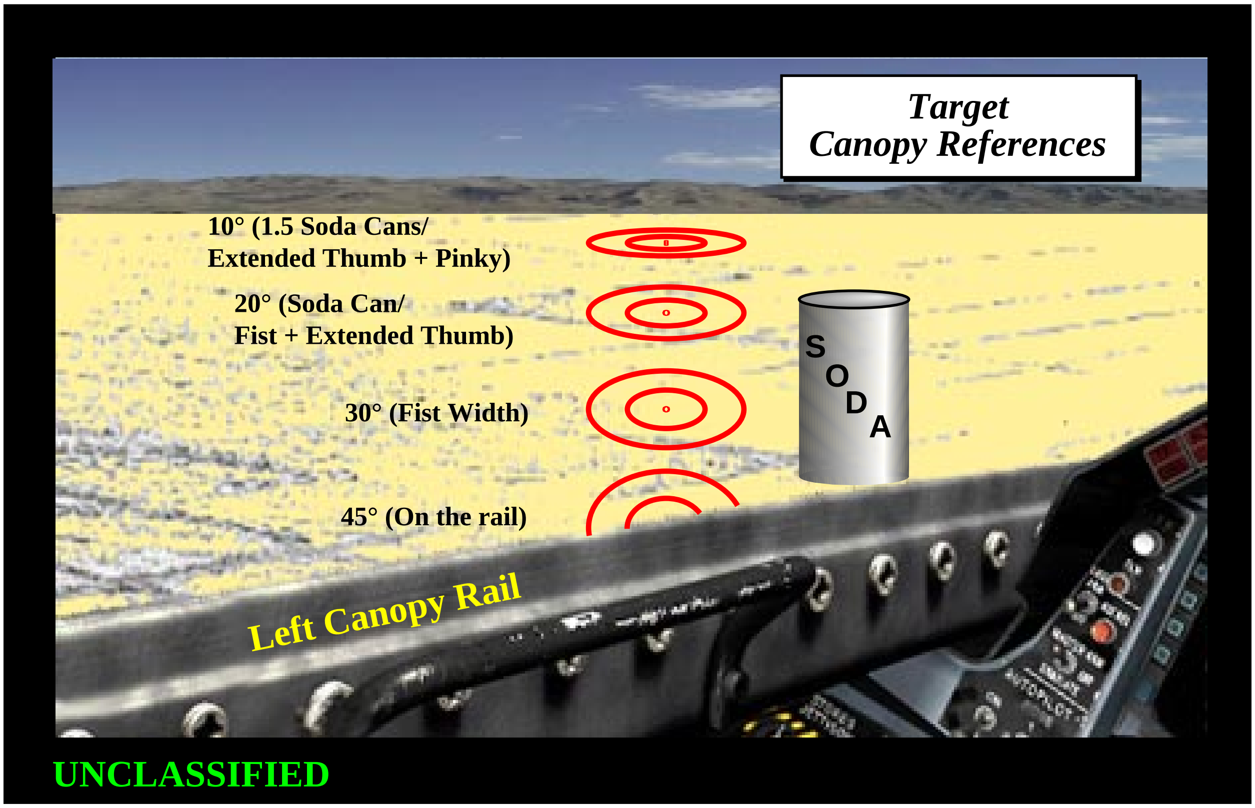
5.13.1.3.2.2. Call turning base (e.g., "THREE, BASE").

5.13.1.3.2.3. Delay your base call (not the turn), if necessary, until the aircraft ahead has received clearance from the range control officer (RCO).

5.13.1.3.2.4. When established on base, check the "sight picture" and make last-minute adjustments in heading to compensate for errors, winds, or actual ground track—adjust airspeed.

5.13.1.4. Roll In. Consider the winds at pattern altitude and adjust the final roll-in point as necessary. As you begin the final turn, determine if you are too close or too wide on base, you may still achieve a proper dive angle by adjusting nose attitude during roll in. Compensate for being too close by over banking and lowering the nose sooner. Avoid an extreme nose-low attitude. Abort the pass if dive angle is over 5 degrees steeper than planned at the roll out (10 degrees if the planned recovery altitude is above 10,000 feet AGL). Compensate for being too wide by reducing bank and maintaining the nose level longer in the final turn. Realize that airspeed on final approach depends largely on power setting. Use Mil power throughout the turn, retarding the throttle to the proper setting on final. Mil power should preclude an inadvertent slow speed/high AOA situation. Lead roll in by one turn radius (usually about 3,300 to 4,500 feet depending on TAS) to prevent angling. The amount of allowable angling varies for different ranges, and depends on RCO judgment. However, up to 10 degrees is normally allowable. Never overfly manned range towers. If it looks or feels bad, go through dry.

Figure 5.29. Target Canopy References.



5.13.1.5. Final. When rolling out on final during any attack, make certain you know exactly which is your target and release ordnance only when you are positive of its identification.

5.13.1.6. Recovery. Recover the aircraft above the minimum recovery altitude regardless of whether ordnance is away or not. Recoveries should be flown IAW Dash 34 safe escape, MCI 11-F16, *Pilot Operational Procedures—F-16*, or minimum altitude for AAA, based on the type of munition, threat, and target area tactics.

5.13.1.6.1. Climbing Safe Escape Maneuver. Normally, a climbing (CLM) safe escape maneuver (SEM) is used for dive angles greater than 20 degrees. After release, obtain 5 Gs in 2 seconds. As the nose approaches the horizon, apply Mil power. G is maintained to a 20-degree climbing flight path angle and then relaxed until 30 degrees.

5.13.1.6.2. Turning Maneuver. For dive angles 20 degrees or less, a climbing or turning maneuver may be used depending on MAJCOM or local guidance. Refer to the Dash 34 for turning maneuver procedure. ***CAUTION***: There are two types of turning maneuvers: Level Turn and Descending Turn—ensure you refer to the appropriate one.

5.13.1.6.3. Level Straight Through Maneuver. For level deliveries at low altitude, another SEM option is the Level Straight Through (LST) maneuver. To fly this maneuver, release at or above the calculated MRA and fly straight and level for bomb TOF plus 3 seconds. Refer to the Dash 34 for further guidance.

5.13.1.7. Turn to Crosswind. Begin the turn to crosswind as soon as the proper SEM is completed and power has been advanced for the climb back to base altitude. Any delay will extend the pattern and present the risk of the following aircraft turning inside your aircraft.

5.13.1.8. Pattern Spacing. Adjust downwind as necessary and place base leg in the proper position every time.

5.13.1.9. Radio Procedures. Refer to MCI 11-F16, *Pilot Operational Procedures—F-16*, "Radio Procedures on a Controlled Range" and consider the following:

5.13.1.9.1. If turning base and the pilot in front of you calls in, allow the range control officer (RCO) to clear him before making your base call.

5.13.1.9.2. Acknowledge all radio calls directed at you except when "cleared" by the RCO.

5.13.1.9.3. Do not hesitate to request clearance if the RCO has not cleared you to drop. ***Do not drop*** without clearance.

5.13.1.9.4. If you go through dry, call, "OFF DRY."

5.13.2. Curvilinear Deliveries. Curvilinear deliveries are used primarily for delivering ordnance from shallow dive angles at relatively low release altitudes. The use of shallower dive angles and lower release altitudes may be required due to the type of ordnance being delivered, weather in the target area, or other tactical considerations.

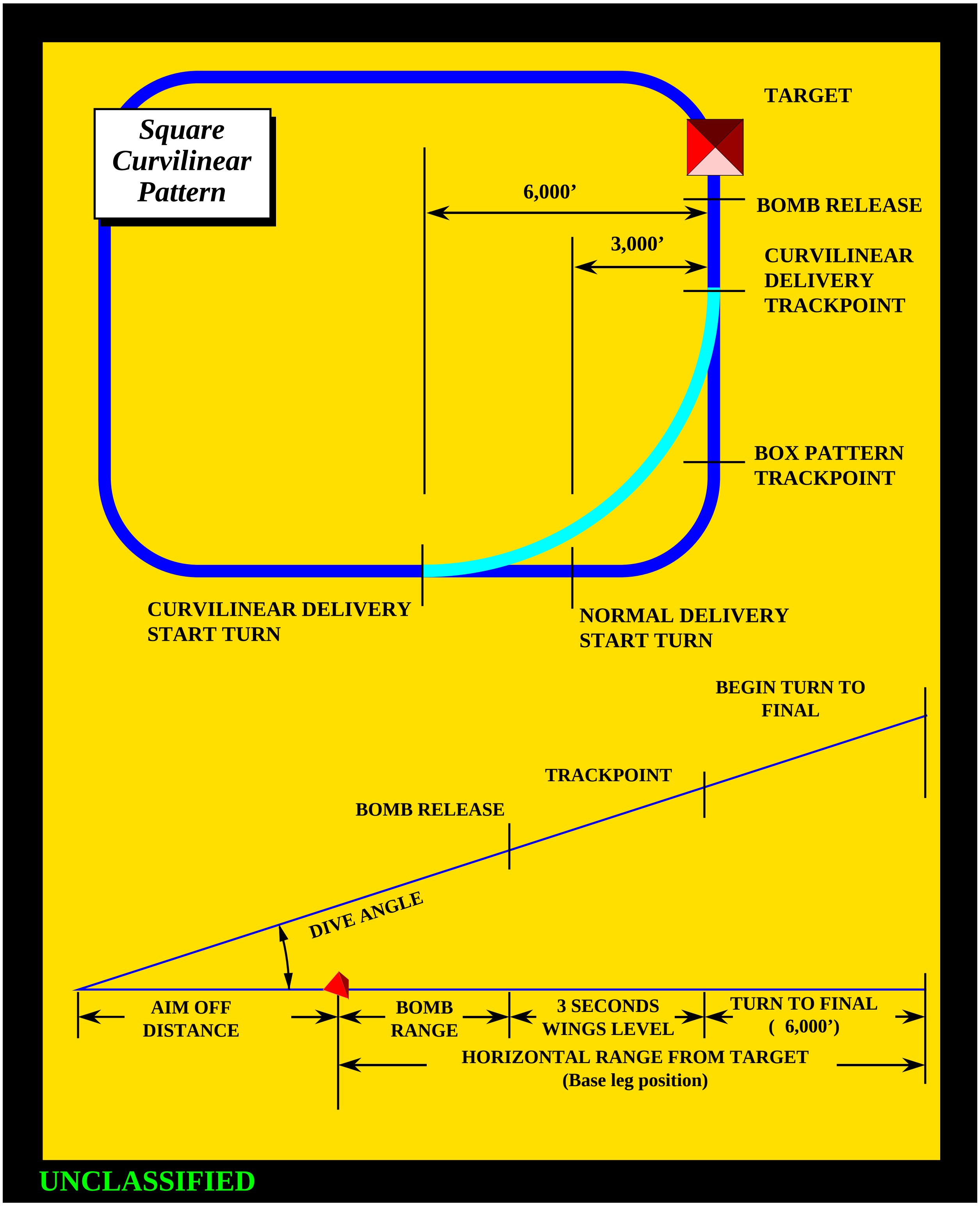
5.13.2.1. Curvilinear Options. A curvilinear approach consists of constantly changing heading, altitude, airspeed, and G-loading to arrive on final for a short tracking solution, thus decreasing AAA hit probability. (See **Figure 5.30.,** Square Curvilinear Pattern.) It may consist of almost any flight path which will allow the pilot to get from roll-in altitude to wings-level on final at the planned track point. The most common technique is a descending turn in 30 to 60 degrees of bank using Mil power initially. Approaching desired release airspeed, retard the throttle as required to hold airspeed. Play the last half of the turn to arrive on final with the BFL through the target for CCIP deliveries. For DTOS deliveries fly the TD box to, or just short of, the target. Cross-check the parameters and make any adjustments necessary to meet the planned release minimums. Designate/pickle and initiate the recovery. This technique is good for LAS, LAHD, LALD, and LLLD deliveries. Curvilinear deliveries may be flown as follows:

5.13.2.1.1. The crosswind, downwind, and base leg are similar to the basic box pattern.

5.13.2.1.2. Begin the curvilinear approach to final at approximately twice the distance of the basic delivery turn to final—6,000 feet prior to an imaginary extended centerline through the target—by lowering the nose slightly, increasing power, and simultaneously establishing a 30- to 60-degree bank.

5.13.2.1.3. Adjust dive angle, power, and bank angle throughout the final turn to arrive wings-level on final with the target approximately two-thirds of the way down the BFL between the FPM and the CCIP pipper for CCIP. Wings-level tracking time on final should not exceed 5 seconds with 3 to 4 seconds desired.

Figure 5.30. Square Curvilinear Pattern.



5.13.2.2. Curvilinear Downwind. Curvilinear deliveries may also be flown by initiating the turn to final from a modified downwind position. The key to starting the pattern from other than the base leg position is to adjust the downwind altitude and position so that a turn can be made to put you at or near the curvilinear base leg position. (See **Figure 5.31.,** Curvilinear Pattern [Continuous Turn].) Fly a higher downwind altitude and make your turn to final a continuous 180-degree turn. However you get there, whether a descending turn or a level turn, the desired objective is to arrive at the planned track point with the proper parameters.

5.13.3. Pop-up Deliveries. Standard range patterns should be established to enable pilots to fly pop-up deliveries to arrive at similar attack parameters as the previously discussed box pattern finals. (See **Figure 5.32.,** Typical Pop Pattern.) Use caution for descending turns at low altitude. Pop-up deliveries may be flown as follows:

5.13.3.1. The base position should be based on a DME range from the target that will allow a descending Mil power turn to point at the target NLT 1 to 2 NM prior to the action point.

5.13.3.2. Accelerate to 480 to 540 KCAS or as required for the delivery action at the specified range. Pop attack planning and execution is discussed in **paragraph 5.14**, Pop-Up Deliveries and **paragraph 5.17**, Pop-Up Formulas.

5.13.4. Radar Deliveries. The radar delivery pattern is used primarily for nonvisual events culminating in system level deliveries or loft deliveries. As shown in **Figure 5.33.,** Radar Pattern, a typical radar bombing pattern is depicted. Use caution when descending to final at low altitude; fly the aircraft first, work the radar second.

5.13.4.1. Fly downwind at the appropriate airspeed and altitude.

5.13.4.2. While on downwind, prepare armament systems as necessary. Evaluate pattern spacing and analyze delivery errors. Analyze winds and adjust pattern as necessary to fly the correct ground track.

5.13.4.3. Turn base at the briefed position.

5.13.4.4. Execute the attack and proper escape maneuver.

5.13.5. Range Departure. When recovering from the last pass, the flight lead will climb while slowing to the planned rejoin airspeed. Prior to rolling in on final for your last pass, attempt to acquire the preceding aircraft. This will make later acquisition easier. Execute a normal pass and recovery.

5.13.5.1. Radio Calls. Report all aircraft you have in sight. Examples:

- “SPAWN TWO, OFF, ONE AIRCRAFT IN SIGHT.”
- “SPAWN THREE, OFF, TWO AIRCRAFT IN SIGHT.”
- “SPAWN FOUR, OFF, THREE AIRCRAFT IN SIGHT.”

Figure 5.31. Curvilinear Pattern (Continuous Turn).

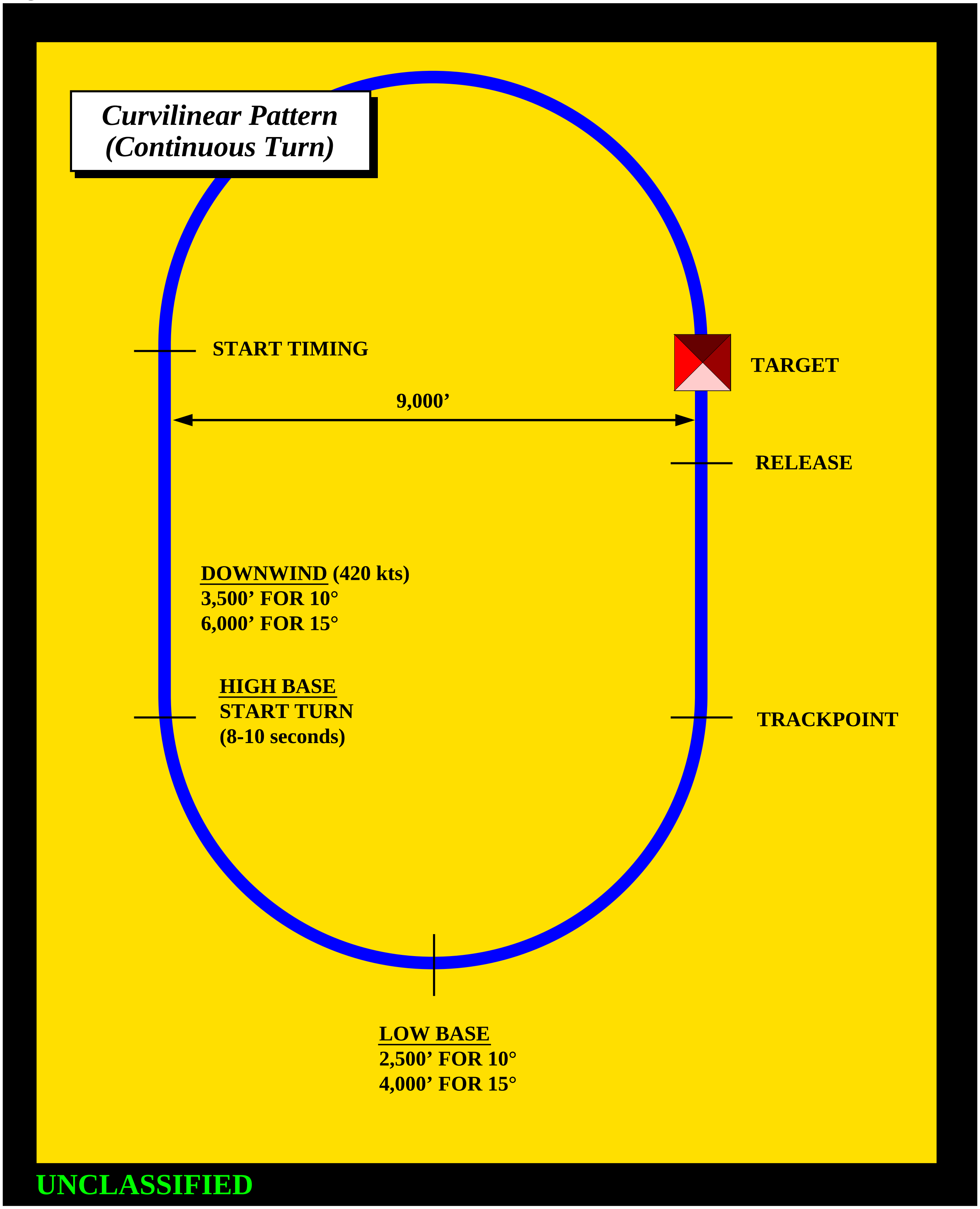
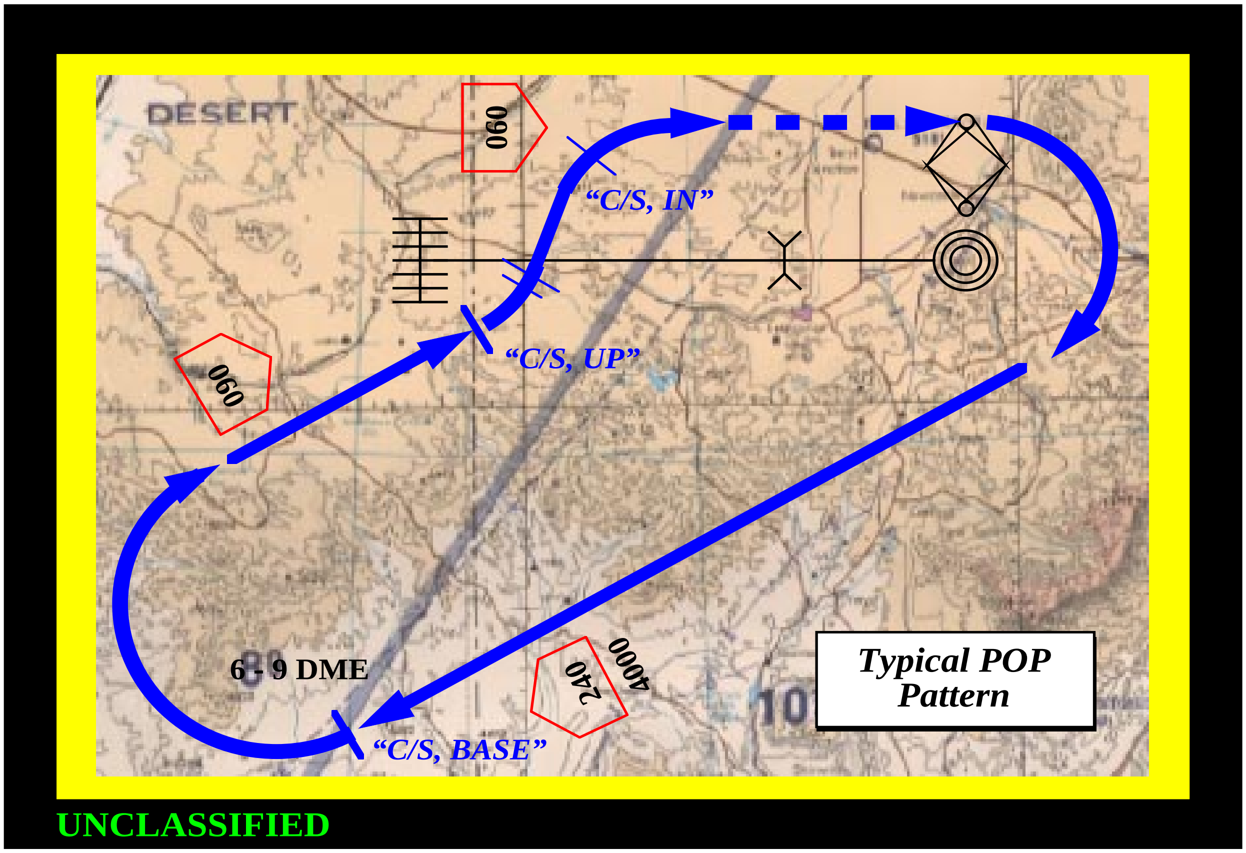


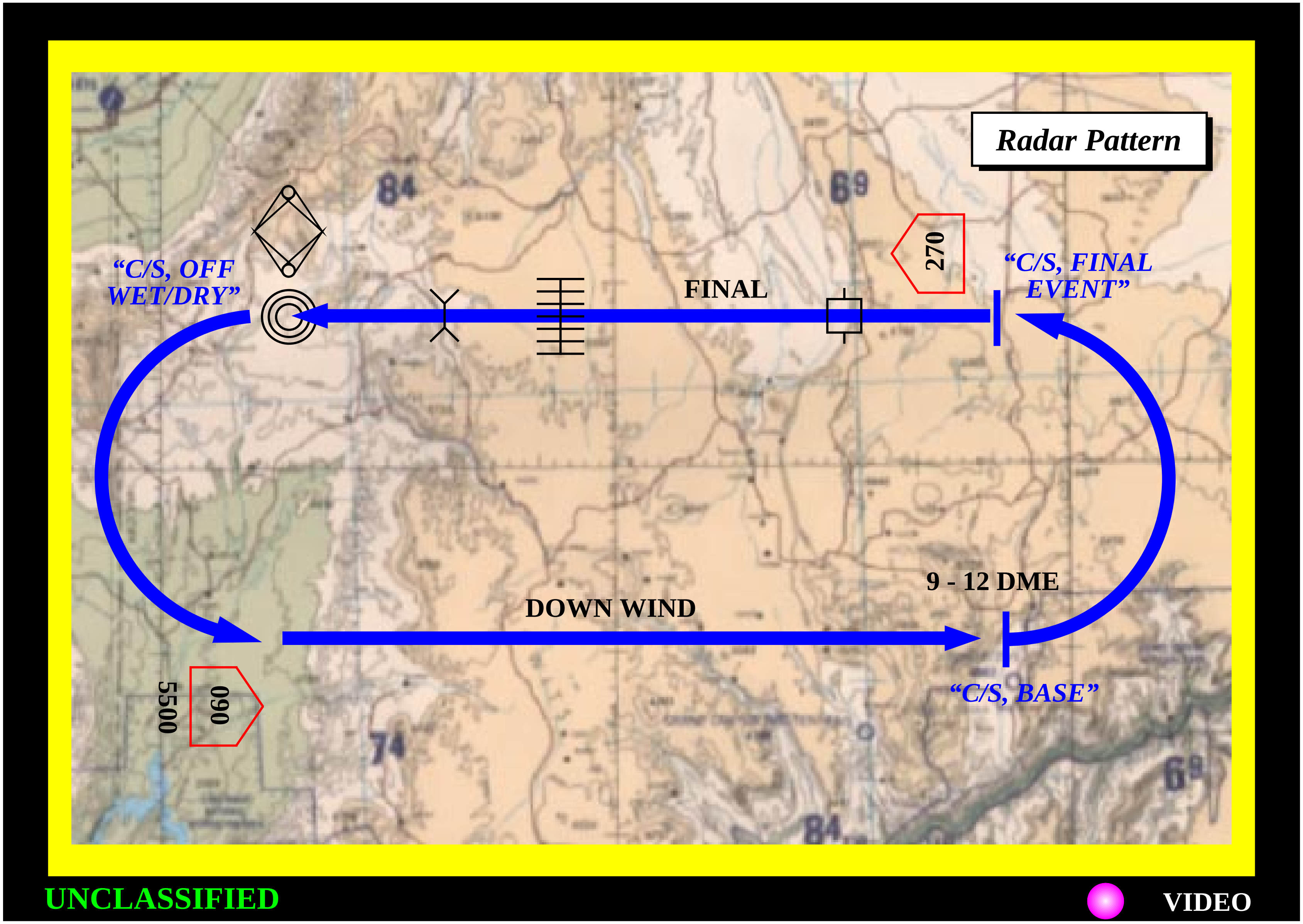
Figure 5.32. Typical Pop Pattern.



5.13.5.2. Blind Off Range. If you do not have visual contact with all preceding aircraft, say so immediately. Do not begin a turn until you have visual contact or until positive altitude separation is assured. Realize that angle-off can be rather high during off-range rejoins. When coupled with high airspeeds, this situation often requires more judgment and skill than do normal rejoins. Avoid dropping low during rejoin. Remember aircraft control takes precedence over a channel change if a frequency change is necessary prior to the rejoin.

5.13.5.3. Safety Checks. At the earliest convenience, safe all armament switches. The flight lead will call for an armament safety check and all wingmen will confirm their switches are safe and acknowledge. Complete an ordnance check when directed.

Figure 5.33. Radar Pattern.



5.13.6. Foul Avoidance. Minimum recovery altitudes are established based upon blast and fragmentation envelopes of live ordnance. These altitudes are generous in that they allow release at the closest possible slant range and still effect a safe and proper recovery. Violation of established minimums places life and aircraft in jeopardy; accuracy seldom improves with such action. The Range Control Officer (RCO), whose decision is final, will issue fouls and/or suspend your operation on the range for any of the following reasons:

- Recovering below minimum altitude.
- Abrupt or dangerous recoveries.
- Firing past the strafe foul line.
- Delivery of ordnance on a wrong or unauthorized target.
- Double bursting strafe.
- Releasing ordnance without clearance.
- Lazy pull-offs.
- Any act deemed unsafe.

5.13.6.1. Multiple Fouls. For the first foul, you will receive a gross error bomb or zero strafe hits for that pass. If the pass was dangerous, you will be ordered off the range. If you are issued two fouls on any mission, the RCO must order you off the range. Climb to prebriefed altitude and safe all switches. Adherence to the following guidelines will aid you in avoiding fouls:

5.13.6.1.1. Know the minimum recovery altitude for each event and do not “press” past the planned release altitude.

5.13.6.1.2. Begin each delivery pattern within proper parameters.

5.13.6.1.3. Avoid any last minute tracking corrections that will carry you past release altitude.

5.13.6.1.4. Do not attempt to observe the ordnance impact. Your most critical task is to safely recover the aircraft above the foul altitude/ground.

5.13.6.1.5. Recover smoothly, using a guideline of 5 positive G's in 2 seconds. Do not bank in an attempt to air score your own bombs.

5.13.6.2. Strafe Fouls. Most fouls come during low-angle strafe, and firing past the foul line is the most common way to get one. Reference to the foul line as well as the entire range environment with your peripheral vision will aid in avoiding this type of foul. Adherence to foul avoidance techniques will also aid in avoiding ricochets. If you are aware of a large number of rounds remaining on the last pass in strafe, consider opening fire a bit further out.

5.13.6.3. Target Identification. Being absolutely sure of your target is not confined to training on controlled ranges; it continues to be a very important factor anytime ordnance is used, even in combat. If you are not certain, GO THROUGH DRY!

5.13.7. Malfunctions. Malfunctions discovered during preflight or any time prior to flight will be isolated or corrected, or abort the aircraft. Circumstances surrounding airborne malfunctions may vary considerably; all will require adherence to proper procedures and good judgment. These malfunctions fall into two basic categories: inadvertent releases and failure to release. Inadvertent releases are rare but serious.

5.13.7.1. Inadvertent Release. An inadvertent release is the jettisoning, firing, or releasing of any ordnance, suspension equipment, or aircraft part which was not commanded by the pilot. If an inadvertent release occurs:

5.13.7.1.1. The incident aircraft will abort, check armament switches safe, and be escorted home following the hung bomb procedures.

5.13.7.1.2. Any remaining ordnance that presents a carriage or landing hazard should be expended in a suitable area (single pass, if practical).

5.13.7.1.3. The pilot should note switch positions at the time of release to clarify subsequent write-ups.

5.13.7.1.4. Initiate aircraft impoundment procedures as outlined in the appropriate AF or 55-series manual.

5.13.7.2. No Release. A no release is commonly caused by incorrectly set switches, releasing the pickle button early (quick pickle), malfunctioning SUU/TER, or an SMS problem. Your first indication of no release will likely be the RCO's declaration of a "no-spot." If switches are correct, suspect hung ordnance. On downwind, recheck the SMS for a RDY indication and note the quantity remaining. If the quantity did not step down, then the SMS never delivered a fire signal. A "quick pickle" (releasing the pickle button too soon) can cause this indication and will result in a no release. Continue in the appropriate delivery pattern, executing dry passes if necessary while analyzing the problem. Re-attempts to expend may be accomplished as long as there are no other apparent malfunctions. ***CAUTION:*** Do not become so engrossed in manipulating switches that you exceed pattern parameters. Certain avionics malfunctions will prevent releases:

- FCC or INS failure: no computed releases, manual deliveries only.
- If the SMS fails completely, you will not be able to release or jettison anything. Other SMS MFLs may indicate partial system or station failures.

5.13.8. Jettison Procedures. Refer to Dash 1 for jettison of external fuel tanks or any unsecure heavyweight/live ordnance. Local procedures describe what to do when jettison is required. Wingmen should notify their flight leader as soon as they think a jettison may be required because it will take time and fuel to set up for jettison. Bingo fuel is not the time to start jettison procedures. Know the Dash 1 jettison limits for the ordnance/suspension equipment you are carrying. Refer to the checklist when forced to land with asymmetrical stores.

5.13.9. RTB and Landing With Hung Ordnance. Refer to MCI 11-F16, *Pilot Operational Procedures—F-16*, "Armament System Malfunction Procedures" and "Hung Ordnance and Dearm Procedures," and local restrictions.

5.13.9.1. Strange Field Recovery With Hung Ordnance. In many cases, the strange fields you encounter in your local area may not be familiar with hung ordnance. The primary item to remember is to ensure the tower is informed as soon as possible, preferably before landing.

5.13.9.2. It is also important to notify the tower if the weapons are live or training ordnance.

5.13.10. Radio Failure. During complete radio failure, exercise good judgment when confronted with a situation not covered in this volume, MCI 11-F16, *Pilot Operational Procedures*, or the flight briefing. Should the situation so dictate, do not be reluctant to use emergency actions which pertain to local flying operations. The following procedures will provide guidelines for actions during complete radio failure:

5.13.10.1. Radio failure after range entry: Refer to MCI 11-F16, *Pilot Operational Procedures***,** Chapter 7**,** and local procedures.

5.13.10.2. RTB with radio failure:

5.13.10.2.1. If there is no standard local procedure to recover with radio failure, be certain that you understand what has been briefed.

5.13.10.2.2. Proceed IAW the briefed procedures if ordnance is hung. Watch for tower signals (flares or lights) or any other conditions which would require a go-around.

5.13.10.2.3. The idea behind hung ordnance patterns is to safely recover the aircraft on the first attempt.

5.14. Pop-Up Deliveries. A highly sophisticated and integrated SAM/AAA/air-to-air threat environment or weather may force a low-level ingress and pop-up attack. While such tactics place us within the AAA and small arms environment, a properly planned and executed pop-up attack should give us our best possible odds against SAM or air-to-air threats and, in addition, can provide surprise and deception to enhance survivability against AAA. There are many variations of pop-up attacks. It is important to understand the basics of the maneuver; namely how to plan and execute each type of attack. Establish habit patterns and use rules of thumb which will ensure successful and safe attacks.

5.14.1. Pop-Up Safety. Target acquisition and alignment with the proper target attack heading are critical on all deliveries. There is little time to decide if you have achieved your desired delivery parameters. If you are faced with parameters that you do not recognize or if you have any doubts about whether or not you should continue the pass, then either abort the pass or reposition. Immediately abort a pop-up attack if any of the following conditions arise:

5.14.1.1. Actual dive angle exceeds planned by more than 5 degrees.

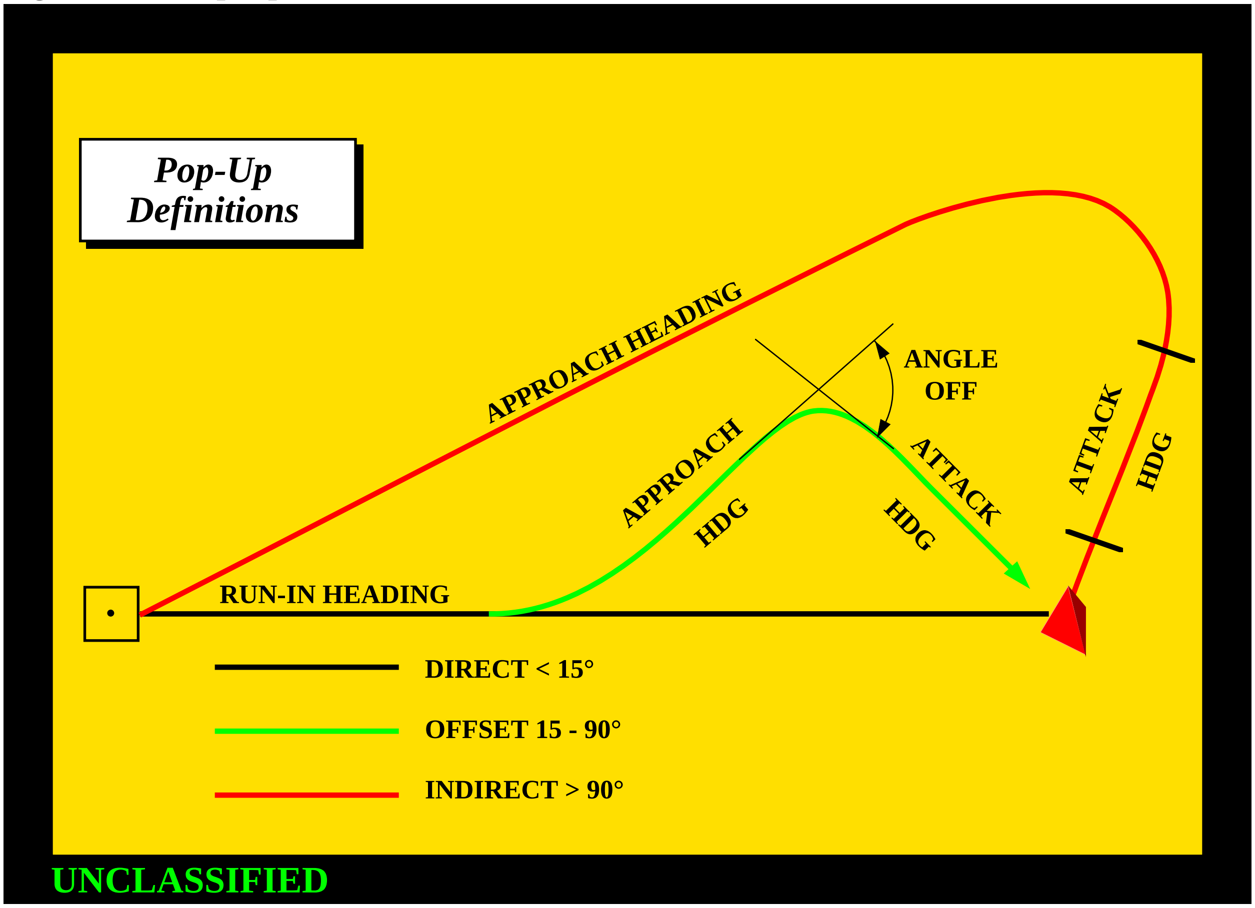
5.14.1.2. Airspeed below 350 KCAS (300 KCAS above 10,000 feet AGL).

5.14.2. Pop-Up Definitions. (See **Figure 5.34.**, Pop-Up Definitions.)

- Approach Heading. The heading flown during wings-level pull-up and climb.
- Attack Heading. The heading flown during wings-level attack. Also called attack axis.
- Angle-Off. The difference between approach and attack heading.

- Direct Pop-up. Angle-off less than 15 degrees.
- Offset Pop-up. Angle-off greater than 15 degrees.
- Indirect Pop-up. Angle-off greater than 90 degrees

Figure 5.34. Pop-Up Definitions.



5.14.3. Offset Pop-Up Definitions. An example is shown in **Figure 5.35.**, Offset Pop-Up Definitions.

- Initial Point (IP). The steerpoint where the last leg to the target begins. Normally, the IP is prominent, unique, and 10 to 20 NM out from the target.
- Action Point/Range. The point/range from the target where you take offset for an offset or indirect pop-up attack.
- Pop Point. A position at which the pop-up attack is initiated. The point where climb is initiated.
- Climb Angle. The angle of climb to be achieved following the initiation of the pop-up.
- Pop-to-Pull-Down Distance. Distance from the pop point to the pull-down point. This distance is predictable for a specific set of delivery parameters.
- Pull-Down Point (PDP). A maneuver point where you transition from the climbing to the diving portion of a pop-up delivery.

- Dive Angle. The selected dive angle for weapons delivery.
- Apex. The highest altitude in the pop-up delivery profile.
- Minimum Attack Perimeter (MAP). An imaginary circle centered on the target equal to the distance from the target at which roll out and tracking begins. The radius of this circle varies with planned delivery parameters.
- MAP Distance. Distance from the MAP to the target. Composed of bomb range and horizontal distance covered while tracking.
- Tracking. That portion of the weapons delivery devoted to the final alignment of the aircraft sighting systems with the target.
- Tracking Time. Wings-level time from roll out to weapons release.
- Horizontal Tracking Distance. The distance traveled across the ground during the tracking time.
- Vertical Tracking Distance. The vertical distance from the track altitude to the release altitude.
- AOD. The ground distance at 12 o'clock from the target where the nose is pointed during tracking.
- Release Altitude. The altitude above the ground at which weapons delivery is accomplished.

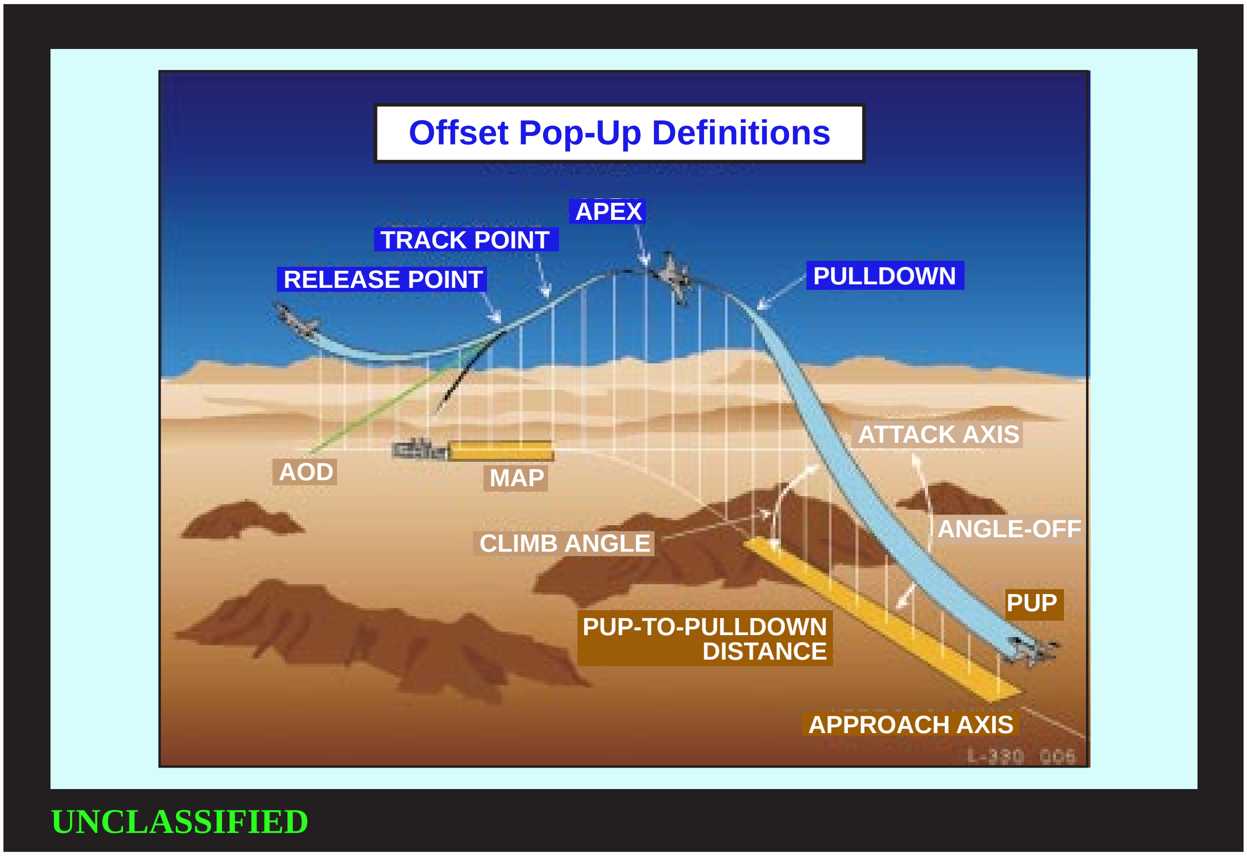
5.14.4. Typical Offset Pop-Up. In this maneuver, the pop-up approach course is at an angle from 15 to 90 degrees from the final attack heading. The approach course angle-off varies with the planned climb angle to permit the pilot to acquire the target as soon as possible and maintain visual contact until completion of weapons delivery.

5.14.4.1. Approaching the Pop-up. The pop-up is initiated over a preplanned pop point (normally with airspeed greater than 450 KCAS). System avionics can aid in finding the planned pop-up point. In CCRP, the air-to-surface target locator line (TLL) helps to confirm desired angle-off. The pop point may be coincidental with this ground reference, or adjacent to it.

5.14.4.2. Initiating the Pop. At the pop point, select desired power (afterburner or Mil) make a 3- to 4-G wings-level pull to the desired climb angle and initiate the desired chaff/flare program. The target should become visible in the front quarter of the canopy slightly off to the side of the planned roll-in direction. Start a visual search for the target just above the canopy rail and over the forward end of the towel rack. After popping, maintain planned climb angle and monitor altitude gained.

5.14.4.3. Pull-down. Approaching the preplanned pull-down altitude, make an unloaded roll in the direction of the target. Perform a 3- to 5-G pull-down to intercept the planned dive angle. Make corrections during the maneuver to compensate for minor errors in the pop point or unexpected winds in the climb to apex at the desired altitude. You normally achieve planned apex altitude about half way through the pull-down maneuver.

Figure 5.35. Offset Pop-Up Definitions.

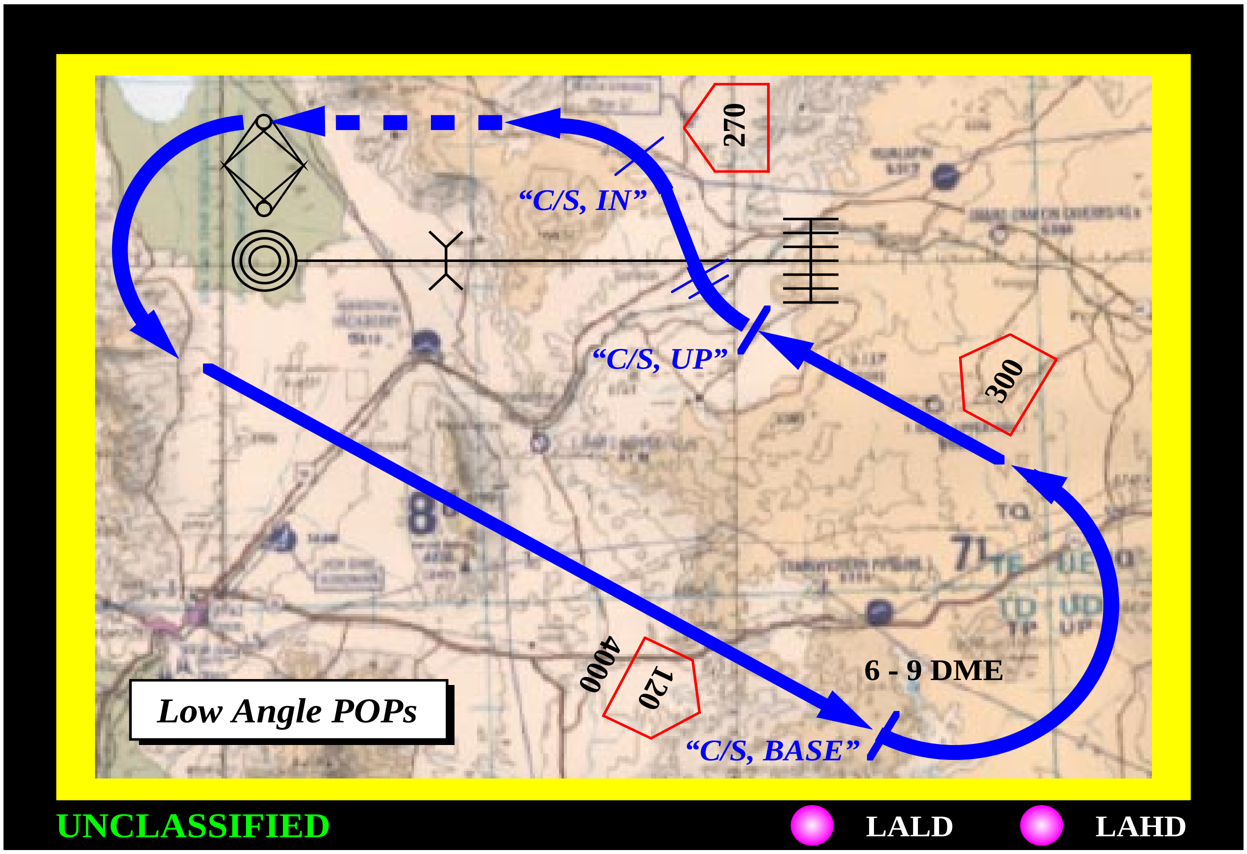


5.14.5. Avionics. The run in is normally accomplished in the CCRP mode. This provides steering to the target in the HUD and system accuracy update opportunities (visual/radar/TGP/ etc.). CCRP will also be valuable from the action point through the final attack axis by providing range, locator line, and ultimately, the TD box on the target (assuming good system accuracy). A good habit pattern is to stay in CCRP until the target is positively identified before stepping to CCIP with the missile step button.

5.14.6. Low-Angle Strafe. Although the planned angle-off from the target can vary, normally the approach to the target is planned to be 15 to 30 degrees from the desired attack heading at approximately 450 KCAS. At the planned pop point, select Mil power and begin a 3- to 4-G pull-up to the desired climb angle. This is normally planned to be equal to the planned delivery dive angle plus 5 degrees. At the preplanned pull-down altitude, roll the aircraft and begin a pull-down to achieve the desired dive angle. Monitoring the HUD pitch lines in relation to the target will simplify achieving the planned dive angle. Roll out with the gun cross just above the target. After roll-out, track and fire just as in a curvilinear/box strafing pass.

5.14.7. Low-Angle High-Drag Bombing (Normally 10 to 15 Degrees). This attack maneuver is very similar to that of low-angle strafe (LAS). It is designed for low-angle delivery of high-drag weapons. The approach to the target is normally planned from a run-in heading offset 15 to 45 degrees from the attack heading at approximately 480 KCAS. At the desired pop point, a 3- to 4-G pull-up is initiated to the planned climb angle (usually dive angle plus 5 degrees). At the preplanned pull-down altitude, the aircraft should be rolled towards the target and the nose pulled down to roll out, the same as you would in any low angle bomb delivery. Normally, this type of delivery is planned to allow 3 to 5 seconds of tracking/ designate time prior to arriving at planned release altitude. For CCIP deliveries, roll out with the target approximately one-half down the bomb fall line (BFL). For manual deliveries, roll out with the FPM (if available) on the correct aim-off point or plan the roll out to place the standby reticle at the pre-computed IPP. (See **Figure 5.36.**, Low Angle Pops.)

Figure 5.36. Low Angle Pops.



5.14.8. Low-Angle Low-Drag Bombing (Normally 10 to 20 Degrees). The delivery is designed for low-angle delivery of low-drag weapons. Exercise care in computing release altitudes to ensure fuze arming and safe escape. Planned angle-off for this type of delivery can vary from 15 to 90 degrees, although optimum angle is approximately 2 x climb angle. Accomplish pull-up to the planned climb angle and pull-down at the preplanned pull-down altitude. Take care to properly monitor the altimeter to determine the proper pull-down point since the apex altitude for a LALD delivery is considerably higher than for a LAHD delivery and visual cues can be deceiving. For CCIP deliveries roll out with the target slightly below halfway between the FPM and CCIP pipper. For DTOS, roll out with caged symbology slightly short of the target. Monitor slant range to ensure proper release parameters. Pay special attention to the altimeter to ensure delivery at or above the planned altitude.

5.14.9. High-Altitude Dive Bombing (Normally 30 to 45 Degrees). This delivery is designed for high-angle delivery of low-drag weapons in a high-threat environment. During mission planning, aircraft configuration must be taken into account to ensure this type of approach is feasible (i.e., two wing tanks with six MK 82s may not be an option for a 45 degrees diving delivery). The approach to the target is normally at 500 to 550 KCAS to an action point 4 to 5 NM short of the target. At this point, a check turn between 20 to 30 degrees is required to obtain the necessary offset. At the desired pop point, a 4-G pull-up is initiated to the planning climb angle (usually dive angle plus 15 degrees) in full afterburner. Once the pop-up is established, primary attention should be devoted to target acquisition. The target may be "hidden" below the canopy rail. Monitor the altimeter as the pull-down altitude approaches due to the rapid climb rate to ensure correct parameters. At the apex, the aircraft will be at or nearly inverted, so care must be taken to roll out with the proper AOD. Attacks should be planned to provide 5 seconds of tracking/designate time prior to arriving at the release altitude. For CCIP deliveries, roll out with the target approximately one-half of the way down between the FPM and CCIP pipper. For DTOS deliveries, roll out with caged symbology short of the target. For manual deliveries, roll out with the FPM, if available, on the correct AOD. If the FPM is not available, plan to roll out with the proper IPP corrected for winds. If the parameters are bad or you have doubts about continuing the pass, either abort the pass or reposition. After releasing weapons, the threat will dictate the type of recovery, but for peacetime training recover with a 5-G pull until the nose is above the horizon then execute the egress plan. (See **Figure 5.19.**, High-Altitude Bombing.)

5.14.10. Visual Level Delivery (0 to 5 Degrees). The visual level delivery (VLD) is flown using CCIP when the weather or threat precludes steeper dive angles. Ingress the target area at low altitude, while terrain masking, and constantly jinking until just prior to weapon release. Since your approach to the target is a random flight path, good planning is required to arrive at an action point where target acquisition is initiated and weapons delivery commenced. If a level delivery is planned, simply arrive at the target on your proper altitude with the CCIP pipper properly positioned. If a 5-degree diving delivery is planned, initiate a 10-degree pull-up followed by a pull-down/bunt approximately 500 feet below planned apex. Pay particularly close attention to precise release parameters and to the fuze arming/pull-up anticipation cue to ensure adequate fuze arming TOF, fragmentation clearance and ground avoidance. The recovery portion of this delivery must be emphasized to ensure safe escape criteria from your munition—know the Dash 34 recovery procedure cold and fly it!

5.15. Pop-Up Planning. Precise planning is the key to destroying the target in low altitude pop-up mission deliveries. Planning begins with the fragged target and ordnance load. The target and its environment may drive some attack parameters. For example, a cave at the base of a hill will drastically limit your choice of attack headings. Weather and threat are also significant factors. Similarly, assigned ordnance may determine attack parameters. Allow enough time to visually acquire a pinpoint target when loaded with MK 82 LDGP. On the other hand, CBU may require less time on final to fine-tune aiming. Once the target and ordnance related restrictions are analyzed, determine the release parameters.

5.15.1. Timing. Determine how much time is needed on final. 3 to 5 seconds of wings-level time is enough for most deliveries. Specialized types of ordnance may require you to spend more time on final. Do not try to minimize exposure time to the point that you will not have time to acquire the target.

5.15.2. Select IP and Attack Heading. Compute the MAP distance and then go back to the chart and choose a prominent and unique IP that will allow you to get to the MAP on an acceptable attack heading. Normally chose an IP 1 to 2 minutes from the target. There are two basic options used to get from the IP to the target: IP-to-pull-up point and depart the IP and fly direct to the target. (See **Figure 5.37.,** IP-to-Target Options.)

5.15.2.1. IP-to-Pull-Up Point. One choice is to fly from the IP directly to the PUP. This approach course will take you direct to the pull-up point and the target area will not remain in the HUD during the ingress.

5.15.2.2. Depart the IP/Direct to Target. The other choice is to depart the IP and fly directly at the target. At a given range from the target, turn to the side for offset and then pop up. Although it looks more complicated, this choice is often quicker to plan and is the much more common choice among pilots. The reason is that the pop portion of the attack is the same for all IP-to-target distances (assuming the IP-to-target distance is outside the action range). Moreover, at any time, you can put the target on the nose and at the action range, turn a preplanned number of degrees to the side, go a preplanned distance, pop, pull-down, and attack. Consider the high-threat close air support (CAS) situation where you do not know the target location prior to contacting the forward air controller (FAC). In this case, the simplest way to make a pop-up attack is to depart the IP (if you have one) with the target on the nose and, at a preplanned action range, turn for offset and execute the attack. Over-reliance on the INS could prevent the safe execution of the attack. A faulty INS could cause you to action late resulting in attack parameters well in excess of that planned. Use all available navigation aids to determine the proper action point (i.e., clock, ground reference points, etc.). As shown in **Figure 5.38.**, Offset Turn at Selected Range, the required information needed to fly directly toward the target prior to executing the attack is displayed.

Figure 5.37. IP-to-Target Options.

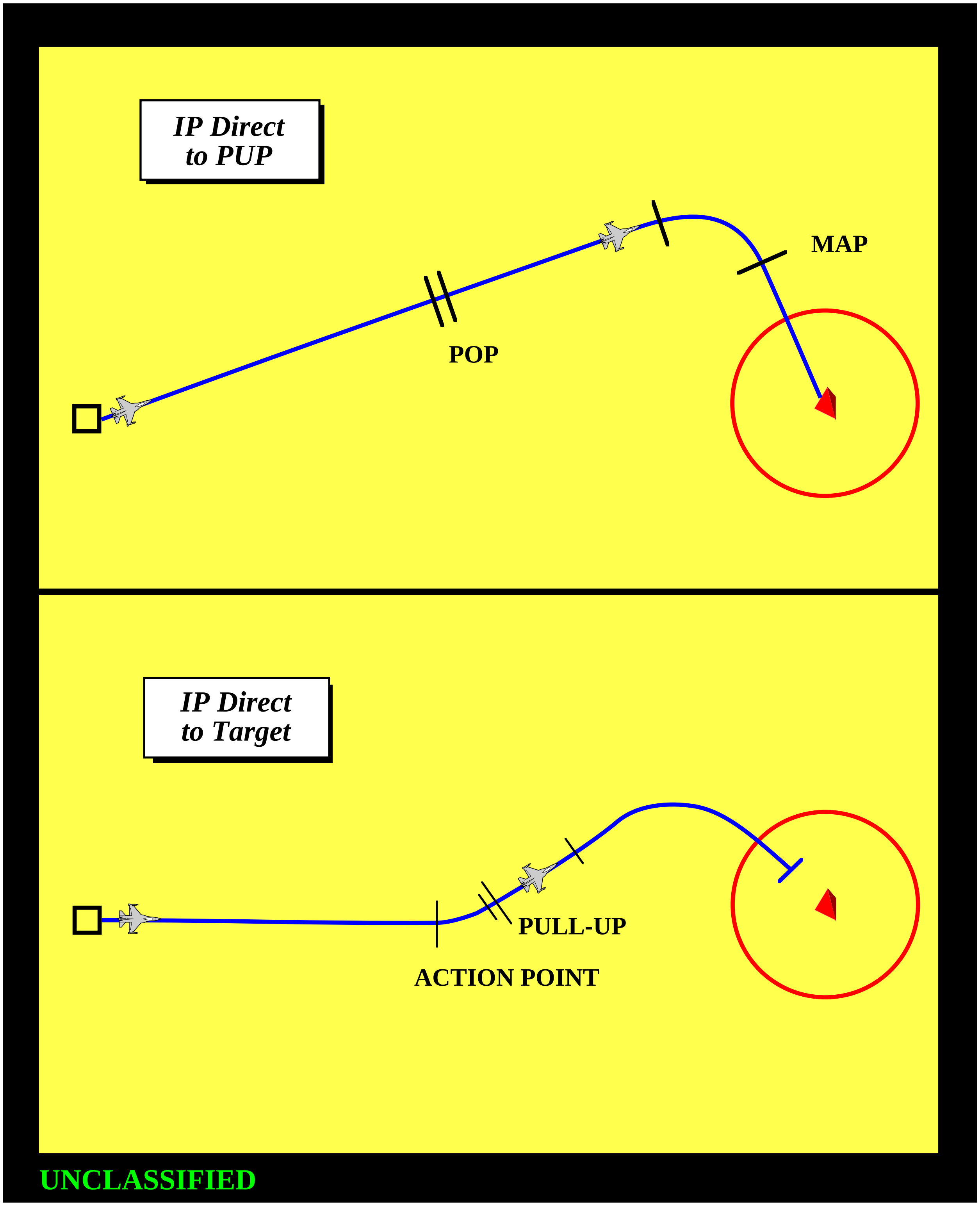
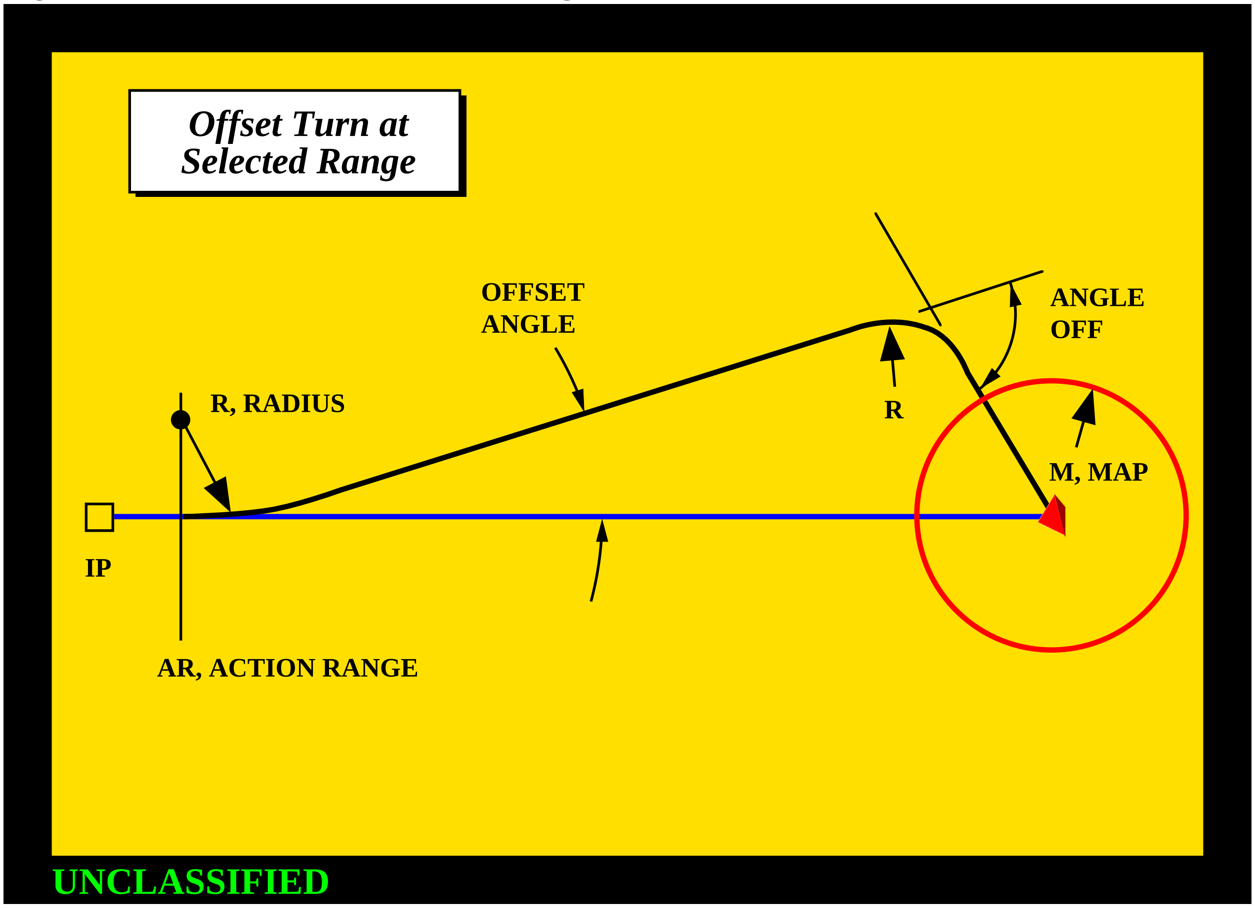


Figure 5.38. Offset Turn at Selected Range.



5.15.3. Planning Element Attacks. When adding a second aircraft to an attack, complications are encountered due to frag and aircraft deconfliction. When multiple aircraft are tasked to attack a target and TOT compression is desired, a potential flight path and fragmentation conflict exists. The fragmentation problem depends on ordnance type, delivery profile, and number of aircraft attacking the target. Deconfliction can be achieved through time, altitude, lateral separation of aimpoints, distance separation from target, or a combination of each.

5.15.3.1. Fragmentation. First, look at the maximum bomb fragmentation travel chart in **Figure 5.39.**, Maximum Bomb Fragment Travel. (For actual data refer to TO F-16-34-1-1. ***NOTE:*** Do not use for planning, use current Dash 34 chart.) This data must be used to determine fragment deconfliction between multiple aircraft attacks. The envelopes present the maximum altitude and maximum horizontal range anticipated for the worst-case fragment of the bomb case, and the time from detonation until all bomb case fragments have settled to the ground. Data is provided for sea level and 5,000 feet target density altitudes. Interpolation between sea level and 5,000 feet and extrapolation up to 10,000 feet are permissible.

5.15.3.2. Time Deconfliction. Time separation between aircraft deliveries must be equal to or greater than the time the preceding weapon's fragments are in the air, plus the delivery

TOF of the preceding munition. To ensure frag deconfliction from the last weapon in the string, attack intervals should include the time required for the ripple/train release.

5.15.3.2.1. 90/90 Maneuver (VEER). The classic method to achieve time separation is to space the aircraft in elements 4 to 5 NM in trail. Line abreast to a trail formation of 4 to 5 NM can be accomplished quickly using variations of a 90/90 maneuver:

- Wingman turns 90 degrees off the ingress heading for approximately 15 seconds.
- After 20 seconds, the flight leader should have traveled 5 NM and the wingman then turns back to the target.
- Some visual contact may be lost; initiate the split close enough to the target to aid in threat acquisition, but far enough out to be able to execute the attack.

5.15.3.2.2. Advantages:

- A more flexible attack is possible if navigation accuracy or target acquisition is questionable.

•Subsequent flight members can bomb off of lead's bomb impact.

5.15.3.2.3. Disadvantages:

- Wingman flies single-ship close to the target area.
- Flight strings out, which reduces visual mutual support and complicates post-attack rejoin.
- Excessive turning in the target area, increasing threat exposure.
- May task saturate the wingman. Maneuver combines aggressive maneuvering, and requires precise flight parameters for success.

5.15.3.3. Altitude Deconfliction. The following aircraft must recover above the maximum altitude for the fragment envelope for the preceding attacker's munition. For example, a 3,265 feet minimum recovery altitude is required for a MK 84 delivery at a 5,000 feet target density altitude. (See **Figure 5.39..**, Maximum Bomb Fragment Travel.)

5.15.3.3.1. Advantages:

- Wingman will have more time to acquire the target.
- High release enables a direct, radar-fuzed CBU delivery.
- Weapon effects improve with increased impact angle.
- Allows simultaneous attacks on a point target.

5.15.3.3.2. Disadvantages:

- Weather must permit higher-altitude deliveries.
- Exposure time for wingmen is increased.
- Depending on release altitude, puts wingman in the heart of threat envelopes.

Figure 5.39. Maximum Bomb Fragment Travel.

Maximum Bomb Fragment Travel

NOT FOR PLANNING - EXAMPLE ONLY

MUNITION	ALTITUDE (FEET) TDA		HORIZONTAL (FEET) TDA		TIME OF FLIGHT (SECONDS) TDA	
	SEA LEVEL	5000’	SEA LEVEL	5000’	SEA LEVEL	5000’
UNITARY WARHEADS						
MK-82 All Types	2140	2500	2550	2900	24.4	25.9
MK-84 All Types	2770	3150	3260	3715	28.0	29.7
BLU-109 All Types	3465	3915	4230	4795	30.3	32.1
INTACT CLUSTERS						
Mk-20 Rockeye	1380	1575	1645	1850	19.4	20.6
CBU-24 B/B: CBU-49 B/B; CBU-52 B/B; CBU-58/B; A/B CBU-71/B, A/B	1895	2140	2290	2595	23.0	24.4
CLUSTER SUBMUNITIONS						
BLU-26/B (CBU-24B/B)	960	1085	1160	1310	16.3	17.3
BLU-59/B (CBU-49B/B)	665	755	775	880	14.2	15.0
BLU-61A/B (CBU-52B/B) BLU-63/B, A/B (CBU-58/B, A/B BLU-86/B, A/B (CBU-71/B, A/B	430	490	490	560	11.6	12.3
BLU-118 (MK-20 Rockeye)	695	790	800	915	14.7	15.5

WARNING The data in this table is for illustration only and should not be used for actual mission planning. Ref 1M-34 for current data

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5.15.3.4. Horizontal Deconfliction. Based on data from the same chart, targets separated by a lateral distance of more than 3,760 feet (TDA 5,000 feet) are clear of the frag envelope. This means that no portion of the delivery and recovery by succeeding aircraft should be closer to the target than the 3,760 feet minimum. If attack headings are not parallel, more lateral spacing between targets is required. Care must be given to ensure neither aircraft intrudes on the other's fragmentation pattern during the egress.

5.15.3.4.1. Advantages:

- Visual contact is maintained throughout.
- Simultaneous attack saturates defenses.
- Reduces flight exposure time.

5.15.3.4.2. Disadvantages:

- Minimal room for accuracy error on the separate DMPIs.
- Flight path conflict over the targets are possible.

5.15.3.5. Aircraft Deconfliction. Depending on target separation, planning for the attack must deconflict aircraft within the attacking element. Types of deconfliction include time, altitude, and horizontal as mentioned above plus attack geometry.

5.15.3.5.1. The direct IP-to-target pop-up planning approach must be modified for a wingman in tactical formation.

5.15.3.5.2. The flight leader must plan the attack so each pilot regains mutual support after the attack while egressing the target area as fast as possible.

5.16. Flying a Tactical Pop-Up. Whether a leader or wingman, there are three things to do that will greatly improve the chances of success: know the profile, navigate precisely, and recognize and correct for errors. It helps to have an attack card on your leg.

5.16.1. Navigation. Navigate precisely and be on speed before the IP. Choose an IP you can easily find and use all available cues to position yourself exactly over it. Use F-16 avionics to improve SA. There are few things worse than to have a threat divert your attention during an IP-to-target run and then try to determine just where you were in the attack. While DR is still important, there are few minds faster than the FCC in determining the what, where, and when of target information. The FCC can significantly enhance SA by providing accurate target location. Know what to load, what help is available, and where to look for it. An understanding of avionics updating is important to fully use the F-16 avionics. However, a frequent cross-check of NAV/GPS status as well as a thorough understanding of the KALMAN filter are required.

5.16.2. Finding the Action. Identification of the action point or pull-up point is crucial to executing the attack as planned. Ground reference, time from the IP, and accurate FCC information make this possible. Accurate planning and assessment of the HUD symbology will improve the overall ability to find the action point.

5.16.3. Camouflage, Concealment, and Deception Considerations. Potential adversaries have the capability of using camouflage, concealment and deception (CCD) techniques to apparently relocate visual IPs and DMPIs. If INS appears to be performing well, and you have confidence in your IP and target coordinates, carefully study INS designated IPs and DMPIs for tone-down or false target insertions. Redesignating on false targets would cause you to miss the target; updating the INS on a falsified IP would degrade an otherwise accurate navigation system.

5.16.4. Recognize and Correct for Errors. There are any number of factors that could possibly prevent accurate positioning at the pull-up point. A few are poor navigation and reactions to enemy defenses. In any case, if you do not get to the proper pull-up point, three things must happen. First, recognize that you are not at the preplanned parameters. Second, assess whether you have sufficient turning room to complete the attack by repositioning from your present position. Third, properly execute a re-attack option, or abort the attack. The key to successful repositioning lies in early recognition of deviations from preplanned parameters. Two broad categories of errors exist in positioning relative to planned pop point and approach course—those that put you outside planned parameters and those that put you inside them. If you find yourself in this situation, consideration should be given to aborting the attack and descending back to low altitude as quickly as possible. Once back at low altitude, then assess the tactical situation and either egress or reattack. However, if conditions permit (low threat, weather, and SA), a repositioning maneuver may allow you to still put bombs on target in the following situations:

5.16.4.1. Pop-up Outside of Planned Parameters. If you pop up and find that you are outside the preplanned parameters, you could be either outside the planned run-in line, or short of the planned pop point. (See **Figure 5.40.**, Outside Pop-Up Parameters.)

5.16.4.1.1. Outside the Run-In. If you are outside the planned run-in line you have the following repositioning options available (listed in order of preference):

5.16.4.1.1.1. Angle in toward the roll-in point during the pull-up.

5.16.4.1.1.2. Apex at a higher altitude to make good the preplanned dive angle, accepting additional tracking time.

5.16.4.1.1.3. Apex at the preplanned altitude, and making the last part of the turn to final fairly level and ease off the G as in a curvilinear pass.

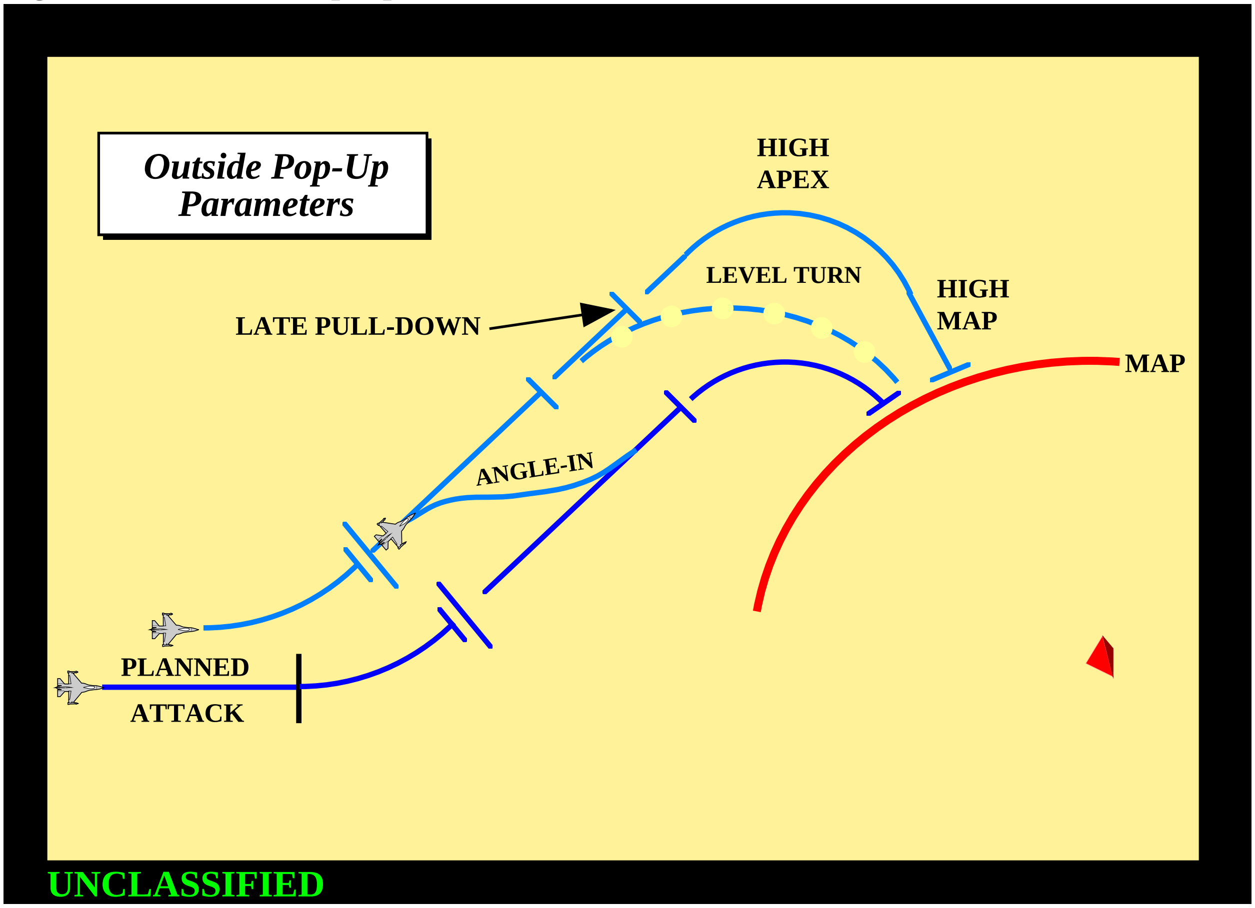
5.16.4.1.2. Early Pop. When the actual pop point was short of the planned pop point:

5.16.4.1.2.1. Reduce G and climb to arrive at the preplanned roll-in point.

5.16.4.1.2.2. Apex at a higher altitude to make good preplanned dive angle and accept a new axis of attack.

5.16.4.1.3. Exposure to Threats. All these options increase exposure time. Tactical considerations will likely determine the course of action to take. In tactical scenarios, anytime you are faced with additional time, make every effort to be unpredictable. Fly a curvilinear repositioning maneuver.

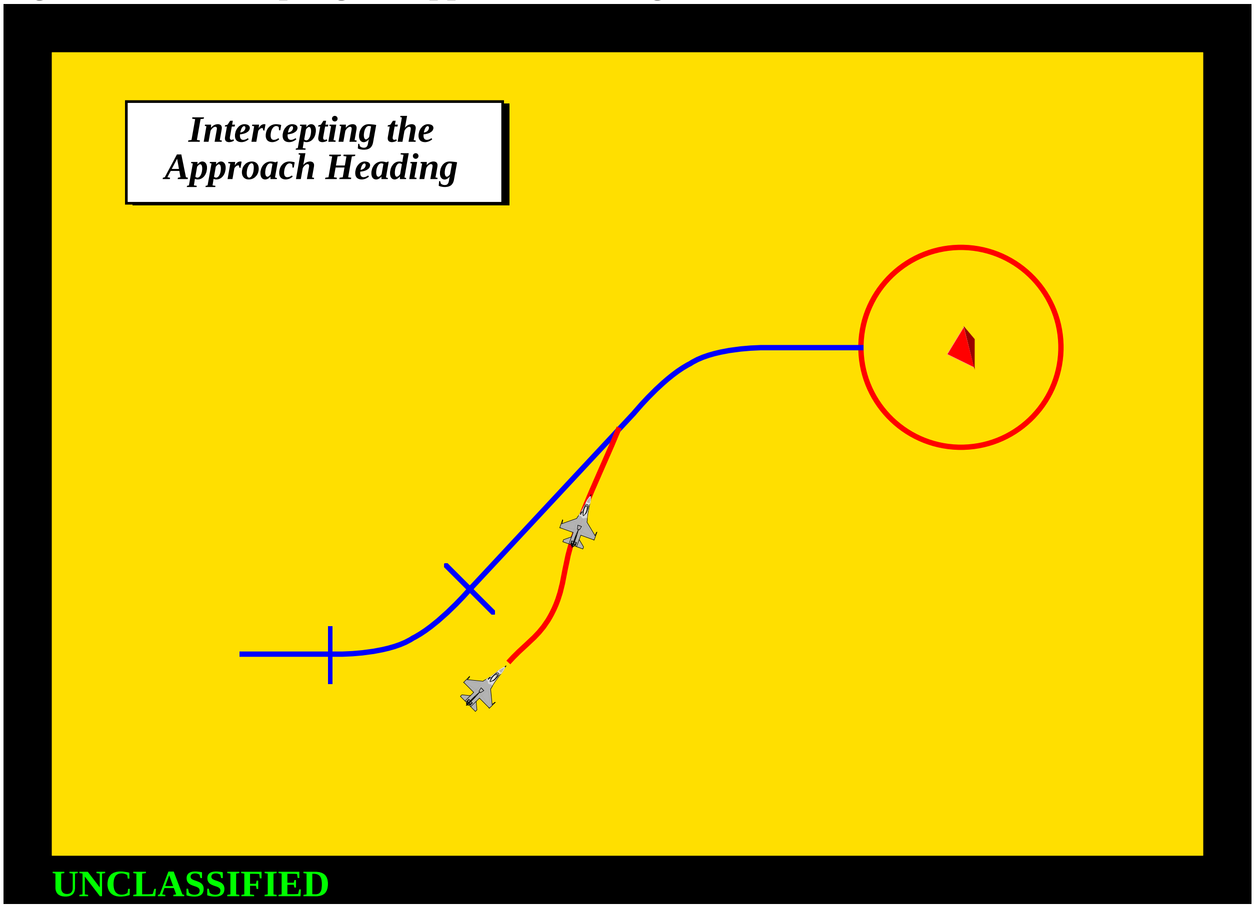
Figure 5.40. Outside Pop-Up Parameters.



5.16.4.2. Pop-Up Inside Planned Parameters. If you pop-up and determine that you are inside planned parameters, you could be either inside the planned run-in line or past the pop point. ***WARNING***: These two situations are more difficult to compensate for, require earlier recognition, and are potentially far more dangerous than the previously discussed errors.

5.16.4.2.1. If you are inside the planned run-in line, you can pull back towards the planned run-in line and intercept it prior to the roll-in point. This is possible if you recognize the error early. (See **Figure 5.41.**, Intercepting the Approach Heading.)

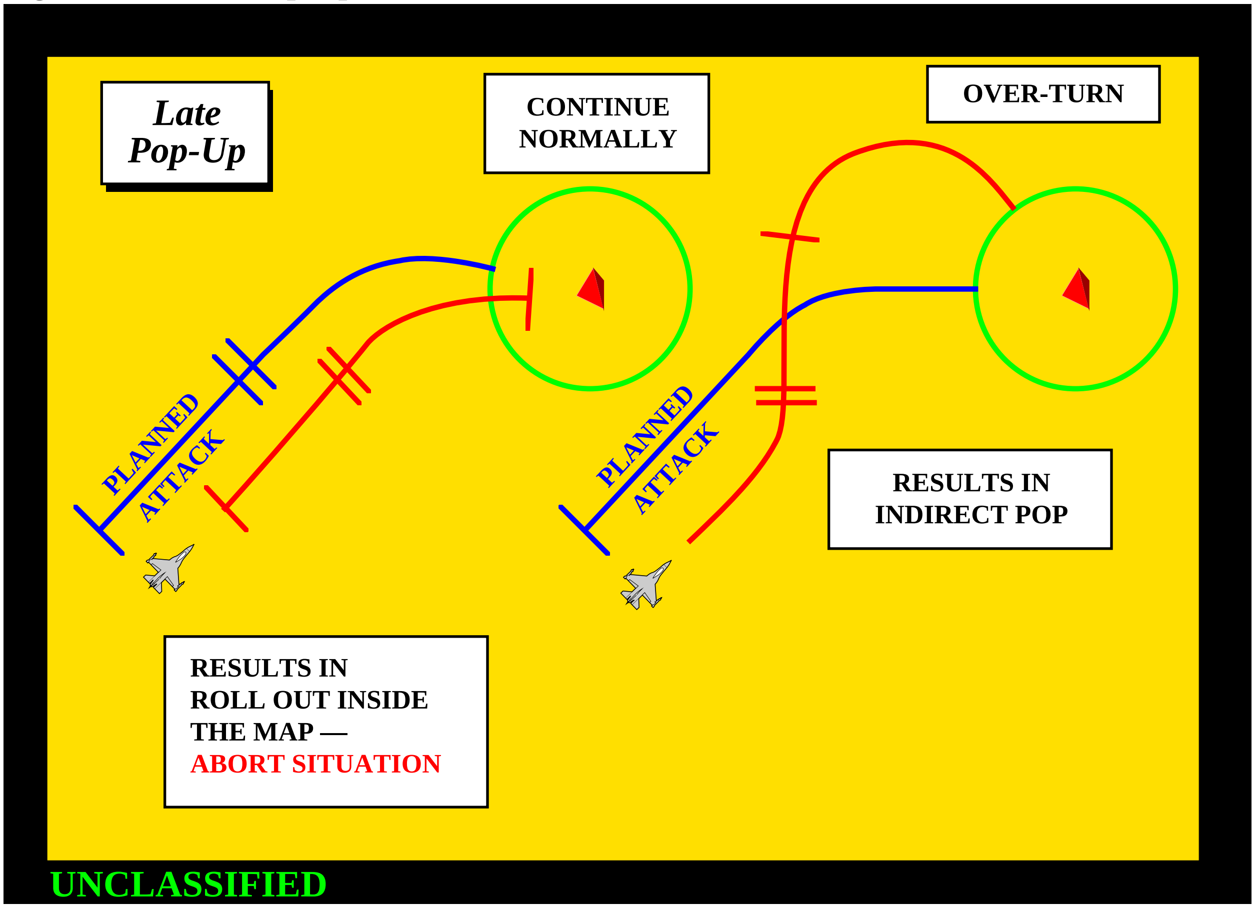
Figure 5.41. Intercepting the Approach Heading.



5.16.4.2.2. If the track point will occur inside the MAP, abort. If you attempt to fly the maneuver on the left of **Figure 5.42.**, Late Pop-Up, you will find yourself rolling out pointed at the AOD well inside the MAP, and probably excessively steep if you went to the planned apex altitude. The example on the right of **Figure 5.42.**, Late Pop-Up, depicts a adjustment outside the planned line, allowing enough room to achieve the MAP. This creates an indirect pop-up situation.

5.16.4.2.3. How do you know you are inside the pop point? A preplanned ground reference point would be one way to tell. Another more common way is to look for the classic picture seen previously. The relationship of the target on the canopy is another indicator. For low angle-off attacks (15 to 60 degrees), the target should not be any further aft than 10:30 or 1:30. For higher angle-off attacks (60 to 90 degrees), the target should not be any further aft than 9:30 or 2:30. In most cases the target should not be hidden by the canopy rail.

Figure 5.42. Late Pop-Up.



5.17. Pop-Up Formulas. There are two methods to complete pop-up planning: use the F-16 CWDS available in the squadron weapons computer; or use the following formulas (all altitudes are in feet AGL) to determine pop-up parameters. Refer to **Figure 5.43.**, Final Attack Diagram, for a diagram and definitions.

- Tracking Distance.

Horizontal tracking distance = GS x 1.69 x tracking time

Where, GS (zero wind) = TAS x cos (dive angle).

Vertical tracking distance = TAS x 1.69 x track time x sin (dive angle)

MAP distance = bomb range + horizontal tracking distance

Track altitude = pickle altitude + vertical tracking distance

AOD = (release altitude)/(tan [dive angle]) - bomb range

Horizontal turn radius = V2/(G_R x g) = (TAS x 1.69)^2/(G_R x 32.2)

g = 32.2 and G_R = cockpit G.

Climb angle = dive angle + 5 degrees for dive angles less than 15 degrees

Climb angle = dive angle + 10 degrees for dive angles less than 15 degrees

Angle off = 2 x climb angle

- Apex altitude. For 3 to 3.5 G pull-down.

Apex altitude = track altitude + (dive angle x 50)

- Apex altitude. For 4.5 to 5 G pull-down.

Apex altitude = track altitude + (dive angle x 37.5)

- Pull-down altitude. For 3 to 3.5 G pull-down.

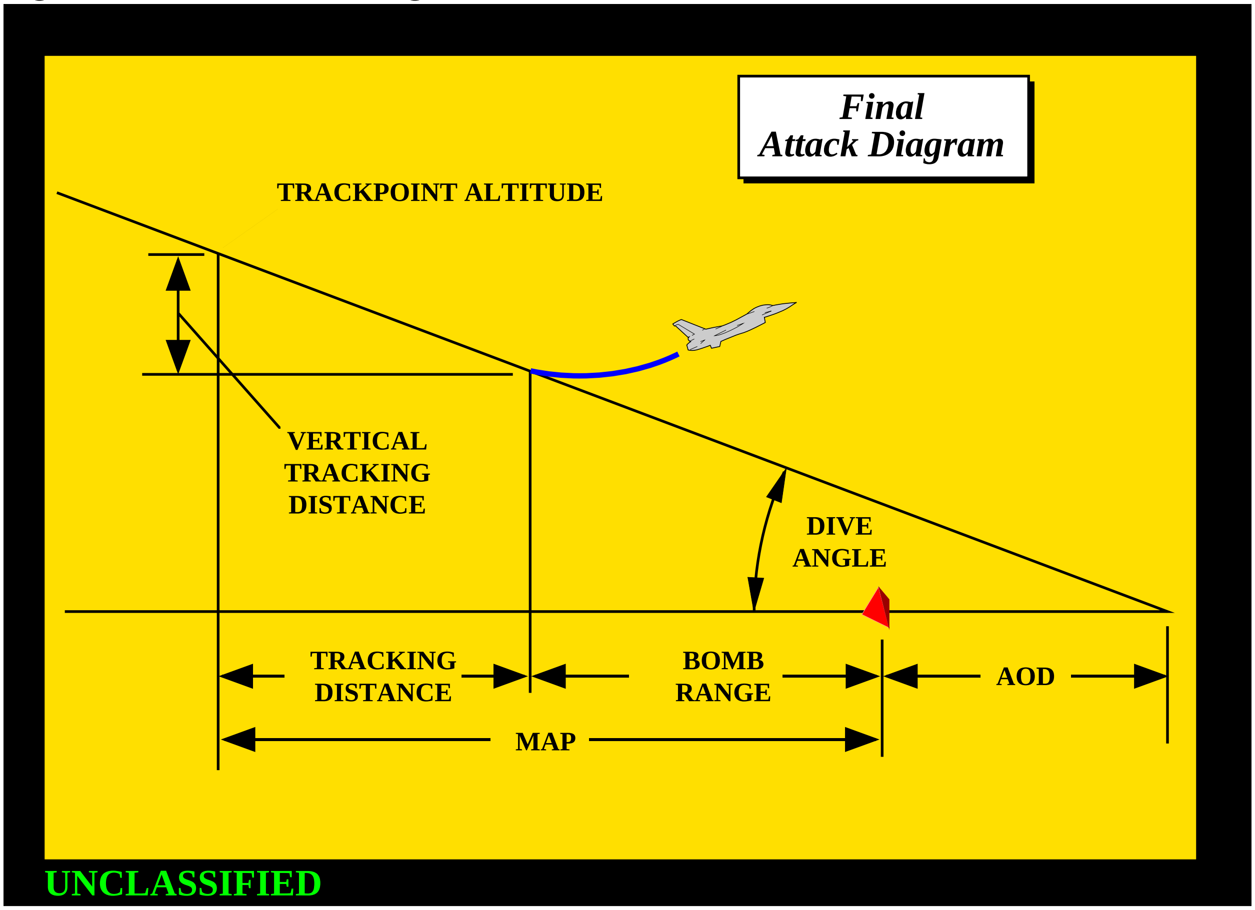
Pull-down altitude = apex altitude - (climb angle x 50)

- Pull-down altitude. For 4.5 to 5 G pull down.

Pull-down altitude = apex altitude - (climb angle x 37.5)

Pop to pull-down distance = apex altitude (AGL) x 60/climb angle

Figure 5.43. Final Attack Diagram.



5.17.1. Sample Pop-Up Computation. Baseline target and ordinance information:

- Target: Tank maintenance complex.
- Ordnance: 6 x MK82 LDGP with M904E2/M905 fuzing set at 4.0 seconds.
- Threat: Will force a pop-up attack but will not affect run-in or attack headings.

- Weather: 4,000 feet scattered and 4 NM visibility.

5.17.1.1. Selected Attack Profile. Make a 15-degree LALD pop-up attack dropping six single bombs at 50-foot intervals. No run-in heading restrictions.

- Release parameters: (From TO 1F-16-34-1-2 Ballistics Tables):
- Dive angle: 15 degrees.
- Release altitude: 2,000 feet.
- Release speed: 520 KTAS.
- Release range to center of stick: 5,138 feet.
- Stick length: 122 feet.
- Time on final: 5 seconds.

MAP distance = bomb range + tracking distance

Bomb range = 5,138 feet (from the Dash 34-1-2)

Tracking distance = 1.69 x GS x tracking time

5.17.1.2. Calculate MAP. The Dash 34-1 tells us that 520 KTAS in a 15-degree dive with no winds equates to about 500 knots GS. This chart is equivalent to the following equation:

GS = TAS x cos (dive angle) = 520 x cos (15 degrees) = 502 knots

Tracking distance = 1.69 x 502 x 5 = 4,242 feet

MAP distance = 5,138 + 4,242 = 9,380 feet

5.17.1.3. Calculate AOD. In this problem, in order to track the target for 5 seconds and then pickle at 2,000 feet AGL, you must arrive at a point 9,380 feet from the target with your nose on the aim-off point. Dash 34 provides additional information:

AOD = (release altitude/tan [dive angle]) - bomb range = 2,000/tan (15°) - 5,138 = 2,326 feet

Vertical tracking distance = 520 x sin (15°) x 1.69 x 5 = 1,137 feet

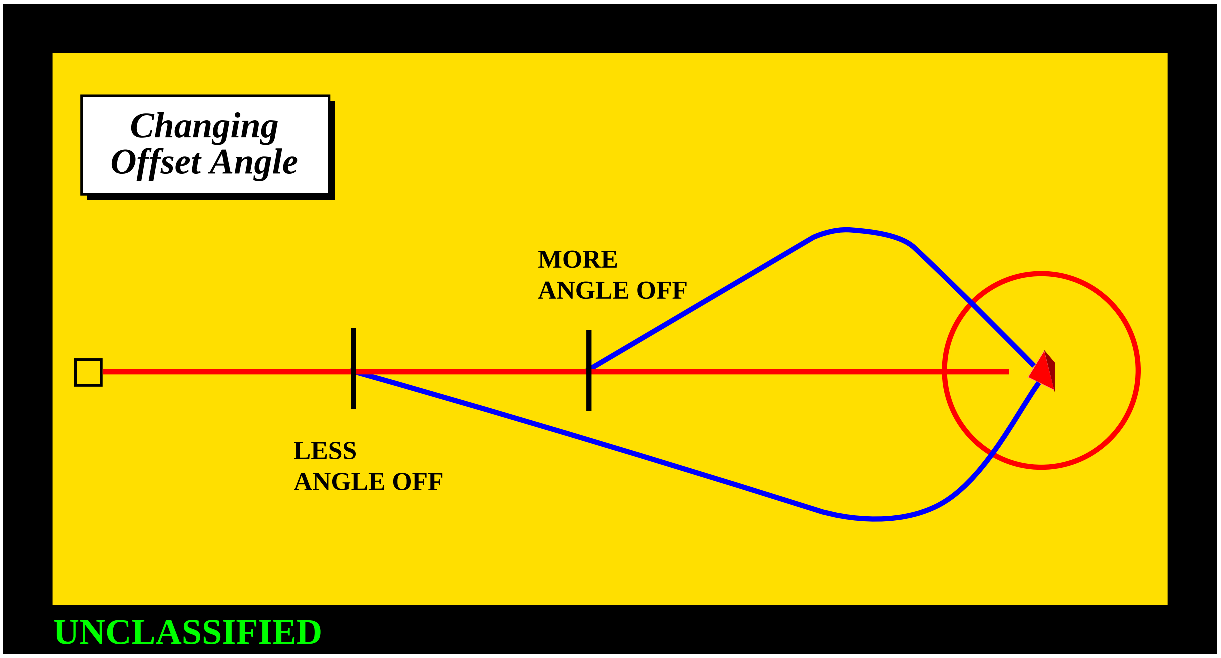
5.17.1.4. Choose the Angle-off and IP. Smaller angles-off will reduce exposure time but make the pop point more critical and repositioning more difficult. Experience has shown that as the dive angle increases, the angle-off also needs to increase to allow the pilot enough time to fly the pull-down and acquire the target. (See **Figure 5.44.**, Changing Offset Angle.) As a general guide, use the following formula to determine angle-off:

Angle-off = 2 x climb angle

NOTE: Dive angles of 15 degrees or less, the climb angle equals dive angle plus 5 degrees.

Angle-off = 2 x (15 degrees + 5 degrees) = 40 degrees

Figure 5.44. Changing Offset Angle.



5.17.1.5. Calculate Pull-down and Apex. Use some other rules of thumb to calculate more required information: pop-to-pull-down distance, apex altitude, pull-down altitude. Actually, there are two choices of rules of thumb to use to derive some of this information depending on the G you want to use in the pop-up maneuver. One set of rules applies for 3.0- to 3.5-G maneuvering and a second set is for 4.5 to 5.0 G's. In this problem, use the rules for the lesser. This choice was made for two reasons: to preserve energy and loosen the maneuver slightly to allow for error corrections. Increase maneuvering as well as decrease the tracking time to make a tighter maneuver thus offering less threat exposure.

Track point altitude = pickle altitude + vertical tracking distance = 2,000 + 1,137 = 3,137 feet

NOTE: For 3.0 to 3.5 G roll-in:

Apex altitude = track point altitude + (dive angle x 50)

Apex altitude = 3,137 feet + (15 x 50) = 3,137 + 750 = 3,887 feet = Approximately 3,900 feet

Pull-down altitude = Apex altitude - (climb angle x 50) = 3,900 - (20 x 50) = 2,900 feet

Pop-to-pull-down distance = (Apex Altitude (AGL) x 60)/Climb Angle = 3900 x 60/2 = 11,700

Turn radius = $(KTAS \times 1.69)^2/(g \times G_R) = (520 \times 1.69)^2/(32.2 \times 3.5) = 6{,}853$ feet

$g = 32.2$ fps^2 and G_R = cockpit G

5.17.1.6. Selecting Action Range. With no restrictions on attack heading, choose the best IP available and then determine the approach heading that will give precisely the angle-off you are looking for, normally, twice the dive angle. Remember, when you fly directly from the IP-to-PUP, the offset angle changes when the IP-to-target distance changes. If you change the IP you may have some replanning to do. Further, it means that the planning for this 15 degrees LALD attack, a very common attack, is only good for one unique IP-to-target distance. Fix the offset angle by turning for offset at a constant distance from the target regardless of the IP-to-target distance. This way, the same pop-up planning can be used even if you must change IPs. In addition, use the same attack plan against other targets (i.e., create a library of pop-up profiles). Use a point 4.5 NM short of the target to take the offset.

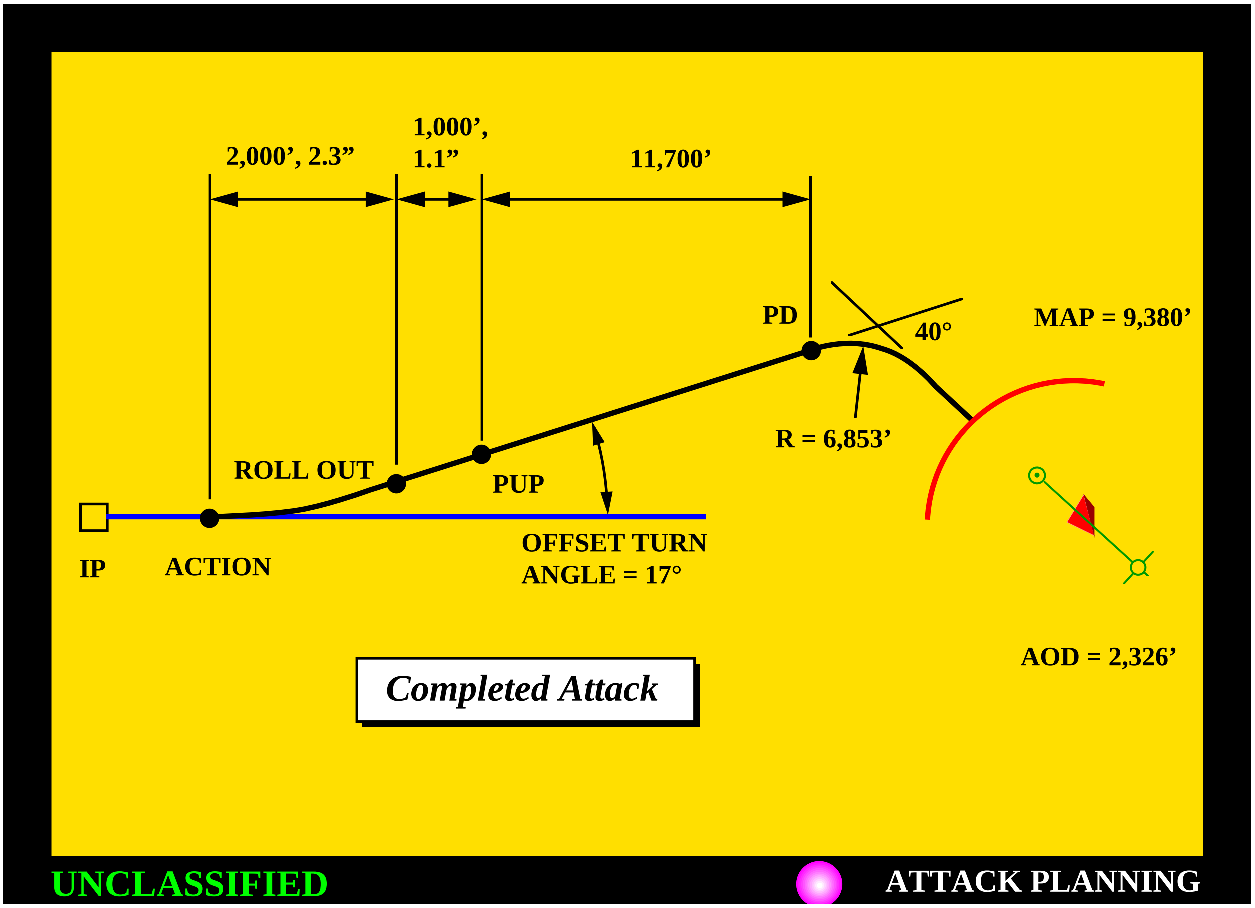
5.17.1.7. Calculating the Hold Down Time. The pull-up point is 11,700 feet prior to the pull-down point as computed from the pop-to-pull-down formula. Measure the distance between the action point roll out and pull-up point. This results in 1,000 feet and requires 1.1 seconds hold-down time prior to pop up.

$$\mathbf{1{,}000/(520 \times 1.69) = 1.1}$$

5.17.2. Drawing the Attack. Once the action point, angle off, turn radius, and pop-up to pull-down distance is defined, draw the attack ground track on a 1:50 or 1:250 Map. The Attack Planning example will give additional attack drawing guidelines. The offset angle can be measured as the difference between the IP-to-target run-in heading and the action heading. The example resulted in a 17-degree check turn at the action point. The action-to-roll out distance can also be measured as the distance between the action point and the point at which roll out is pointed at the pull-up point and reflects a constant 3- to 3.5-G turn. This distance is measured to be 2,000 feet for our example computations. A visual depiction of these results are shown in **Figure 5.45.**, Completed Attack.

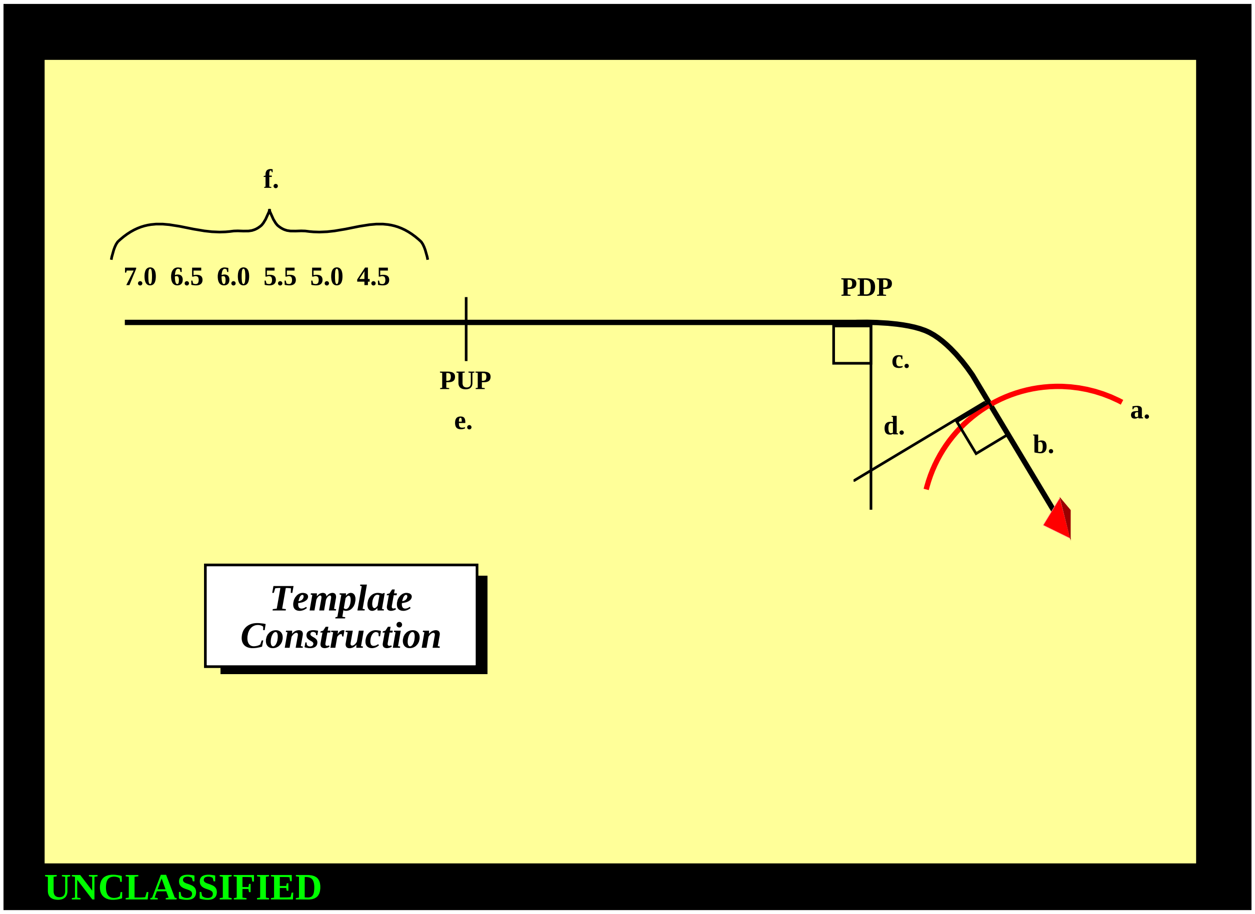
5.17.3. Using Computers. The squadron weapons shop will have a program on the weapons/ flight planning computer that will quickly compute the majority of the pop-up parameters.

Figure 5.45. Completed Attack.



5.17.4. Preparing Templates. If you draw the attack to scale to do a map study, this allows the second alternative for determining attack information and graphics. You may draw the attack directly on the map, but it is better to make a template out of a piece of paper or light cardboard. Use the template to adjust the attack profile and finally trace it on the map. In addition, add the template to the library of attack options. To make a template, decide on a scale. A 1:50,000 scale is suggested for two reasons: to derive headings and distances graphically, a scale large enough for accuracy is needed; and trace the profile on a 1:50,000 scale-map, this type map is commonly used in attack planning. Some paper or light cardboard, a plotter and a compass or circle template (if you want round circles) is needed. (See **Figure 5.46.**, Templates Construction).

Figure 5.46. Templates Construction.



5.17.5. Finished Attack. For the example, pop-up calculations were used to plan the following attack:

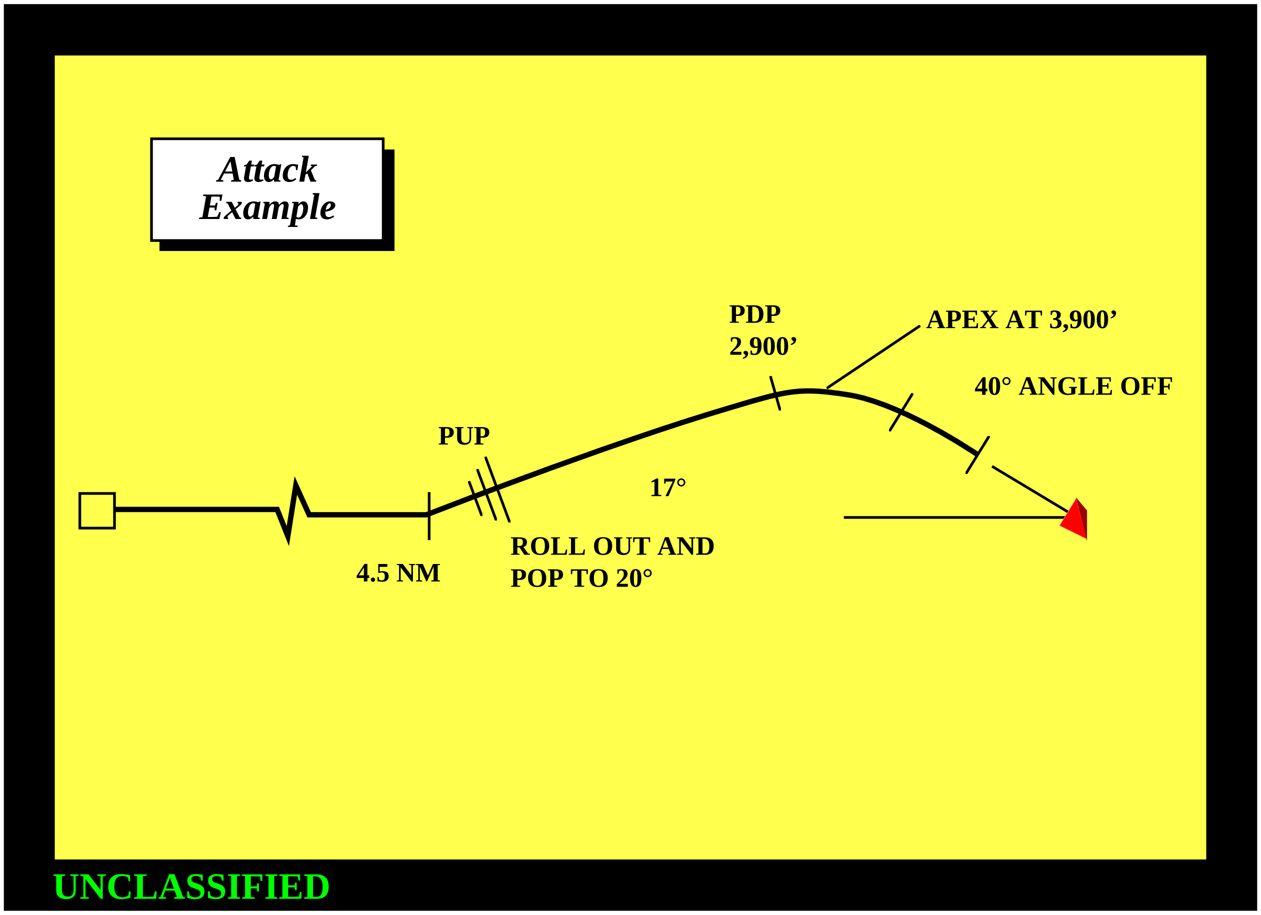
- Dive angle: 15 degrees.
- Release altitude: 2,000 feet.
- Approach and release airspeed: 520 KTAS/500 KCAS.
- Time on final: 5 seconds.
- AOD: 2,326 feet.

5.17.6. Attack Description. An example is shown in **Figure 5.47.,** Attack Example. A stick figure drawing may be included on the line-up card for easy access.

- Put target on the nose.
- At 4.5 NM take 17 degrees offset with a 3.5-G turn.
- Roll out and immediately pull up to a 20-degree climb.
- At 2,900 feet AGL, roll towards target.

- Pull down with 3.0 to 3.5 G's. The heading change should be approximately 40 degrees.
- Roll out at 3,137 feet in 15 degrees dive with the FPM 2,326 feet beyond target.
- Pickle at 2,000 feet.

Figure 5.47. Attack Example.



5.18. Fly-Up Attacks. Fly-up attacks are a derivative of the pop-up attack and are primarily used in the low-threat environment where AAA, small arms, and IR SAMs are the primary threats in the target area. Ingress is at low altitude due to en route threat or to effect tactical surprise. The fly-up is initiated at a distance from the target that allows a pull up to the base altitude of the planned delivery with a 10- to 15-degree climb angle. Once at base altitude, the delivery is a curvilinear delivery with emphasis placed on recovery above the AAA/small arms envelope. Emphasis must be on element mutual support and accurate weapons delivery.

5.18.1. Sanitize the Target Area. The flight should use radars to sanitize the target area for airborne threats prior to the fly-up. Ingress and attack the target only when the whole attack and egress can be completed without enemy aircraft engagements.

5.18.2. Executing the Fly-Up. Fly-up at 10 to 8 NM from the target. The flight lead will check 10 to 20 degrees away from the target and initiate a climb (using AB, if necessary) to arrive at base altitude in a position to execute a high-angle delivery.

5.18.3. Wingman Considerations. When lead executes the fly-up, the wingman's primary job is visual lookout. Fly-up to place yourself in a position to visually support lead and execute the planned attack.

5.19. Two-Ship Employment Considerations. Deconfliction methods can include split, echelon, trail, shooter cover, and loft.

5.19.1. Deconfliction Options. To achieve altitude separation, the first aircraft can use a level, low-angle pop-up, VLD delivery, offsetting as necessary for the planned delivery. The second aircraft splits at a predetermined point and pops to a high LALD or dive bomb delivery and pulls out above the frag envelope. (See **Figure 5.48.,** Split, Altitude Deconfliction.) To achieve distance deconfliction, the second aircraft can use LAT or a loft delivery pulling out with separation from the frag. (See **Figure 5.49.**, Split, Distance Deconfliction.) For timing separation a split at sufficient distance to achieve the desired spacing is effective but reduces mutual support after the split. (See **Figure 5.50.,** Split Time Deconfliction.) A split closer to the target requires arcing to remain within visual range and achieve timing separation. This allows the second aircraft to drop from a low-altitude delivery. The distance of the arc from the target depends on the turning room necessary to achieve delivery parameters.

5.19.2. Split Pop Attack. This option is designed for minimum exposure while splitting the defenses. Deconfliction can be achieved through altitude, distance, or timing. ***WARNING***: Altitude deconfliction may put the wingman into the heart of some threats. Use altitudes that recover above the threat versus frag to the maximum extent possible.

5.19.3. Echelon Pop Attack. An echelon pop has both aircraft offset to one side of the target. This attack allows the element to maintain visual contact during the ingress, and allows the wingman to fly a visual formation during the attack. Deconfliction can be achieved through altitude, timing, and distance. Both aircraft turn away from the target at a predetermined point for offset pops. The lead aircraft can use a minimum exposure delivery such as VLD. The second aircraft can achieve altitude separation by popping to a high LALD or dive bomb delivery and pulling out above the frag. (See **Figure 5.51.,** Echelon, Altitude Deconfliction.) Timing separation by arcing (**Figure 5.52.,** Echelon, Time Deconfliction) or distance deconfliction by using LAT (**Figure 5.53.,** Echelon, Distance Deconfliction) may also be used. ***WARNING***: Altitude deconfliction increases the wingman’s vulnerability to many threats. The requirement for high power settings (AB) and long unmask times allows threat acquisition and engagement. Use altitudes that recover above the threat versus frag to the maximum extent possible.

Figure 5.48. Split, Altitude Deconfliction.

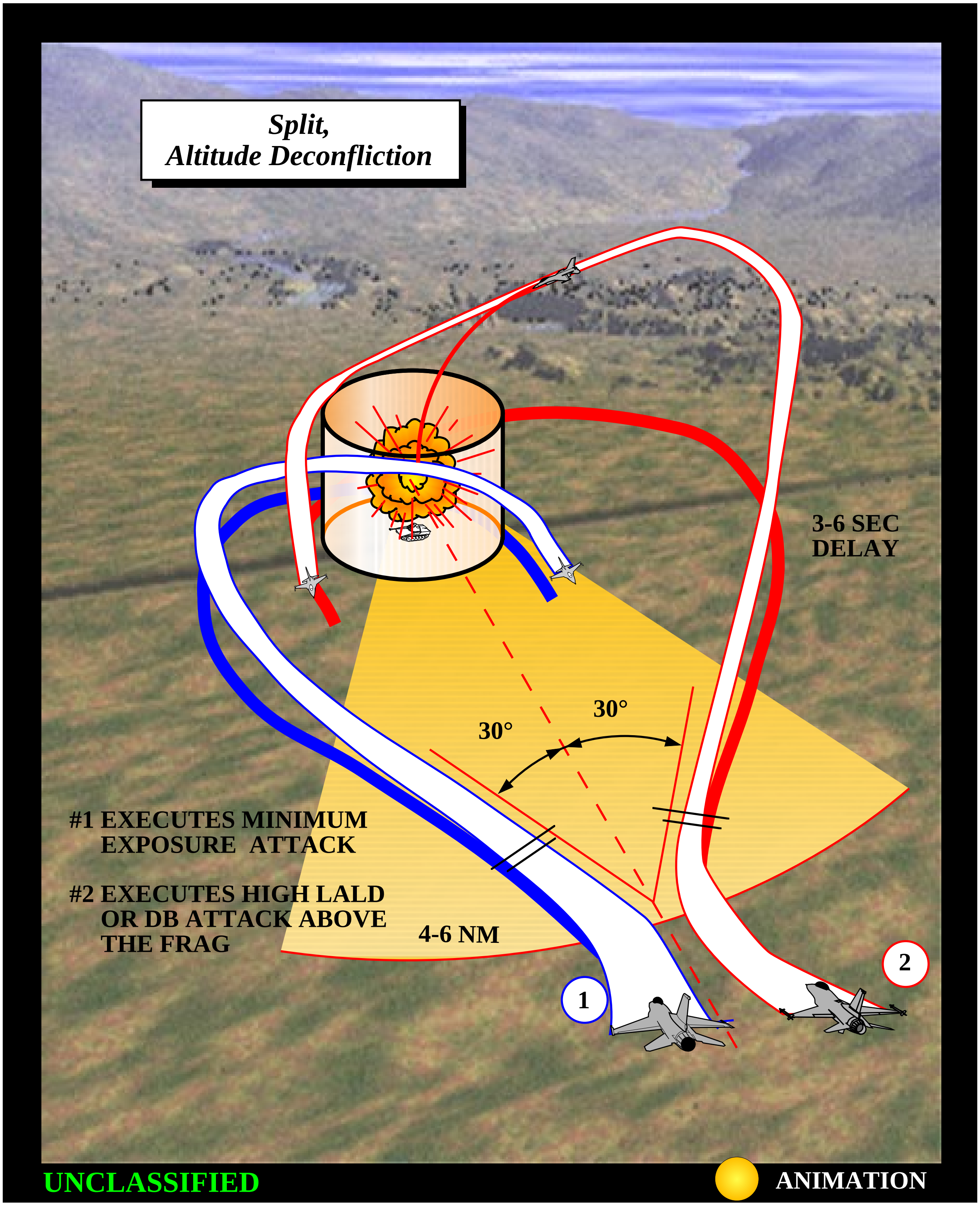


Figure 5.49. Split, Distance Deconfliction.

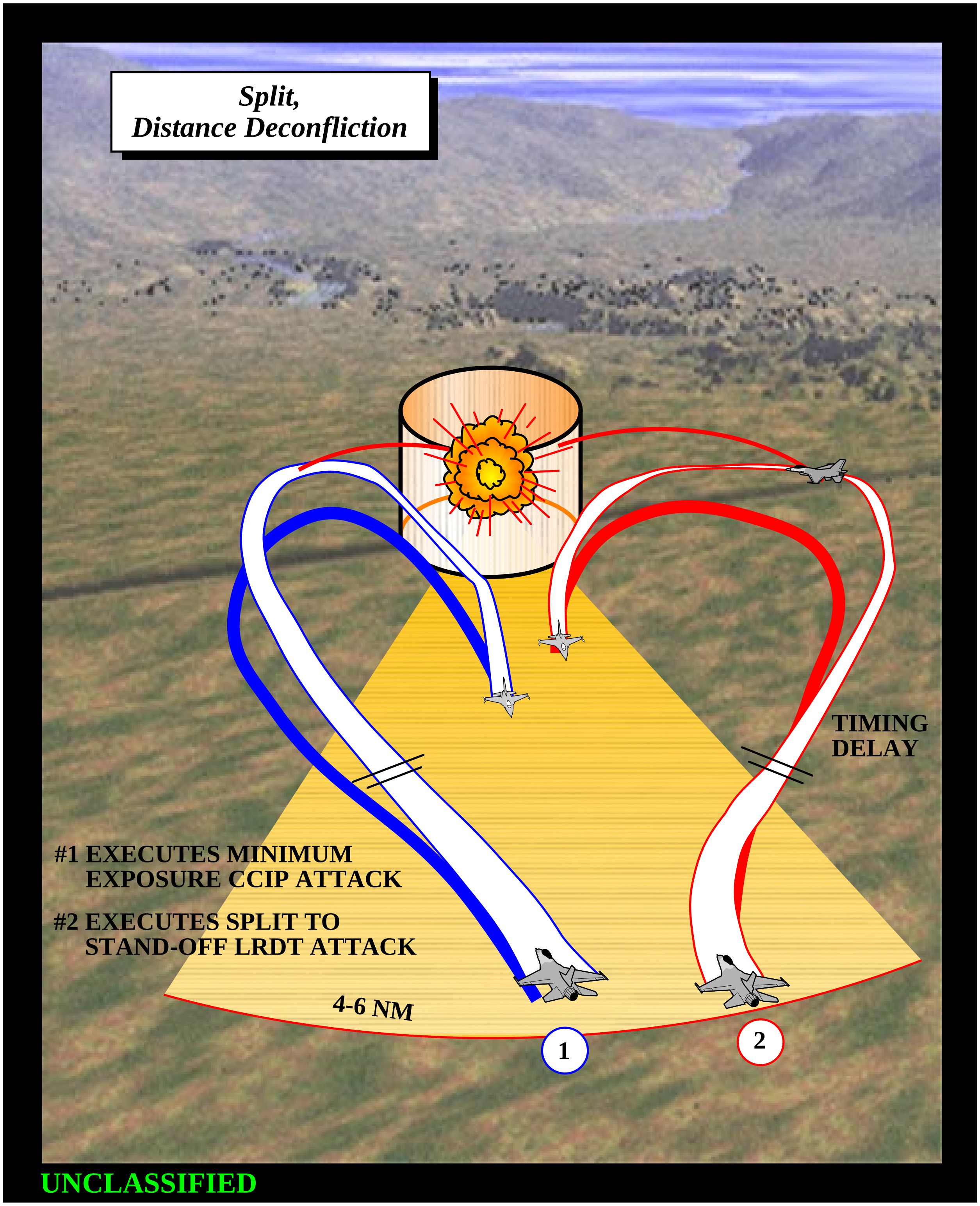


Figure 5.50. Split Time Deconfliction.

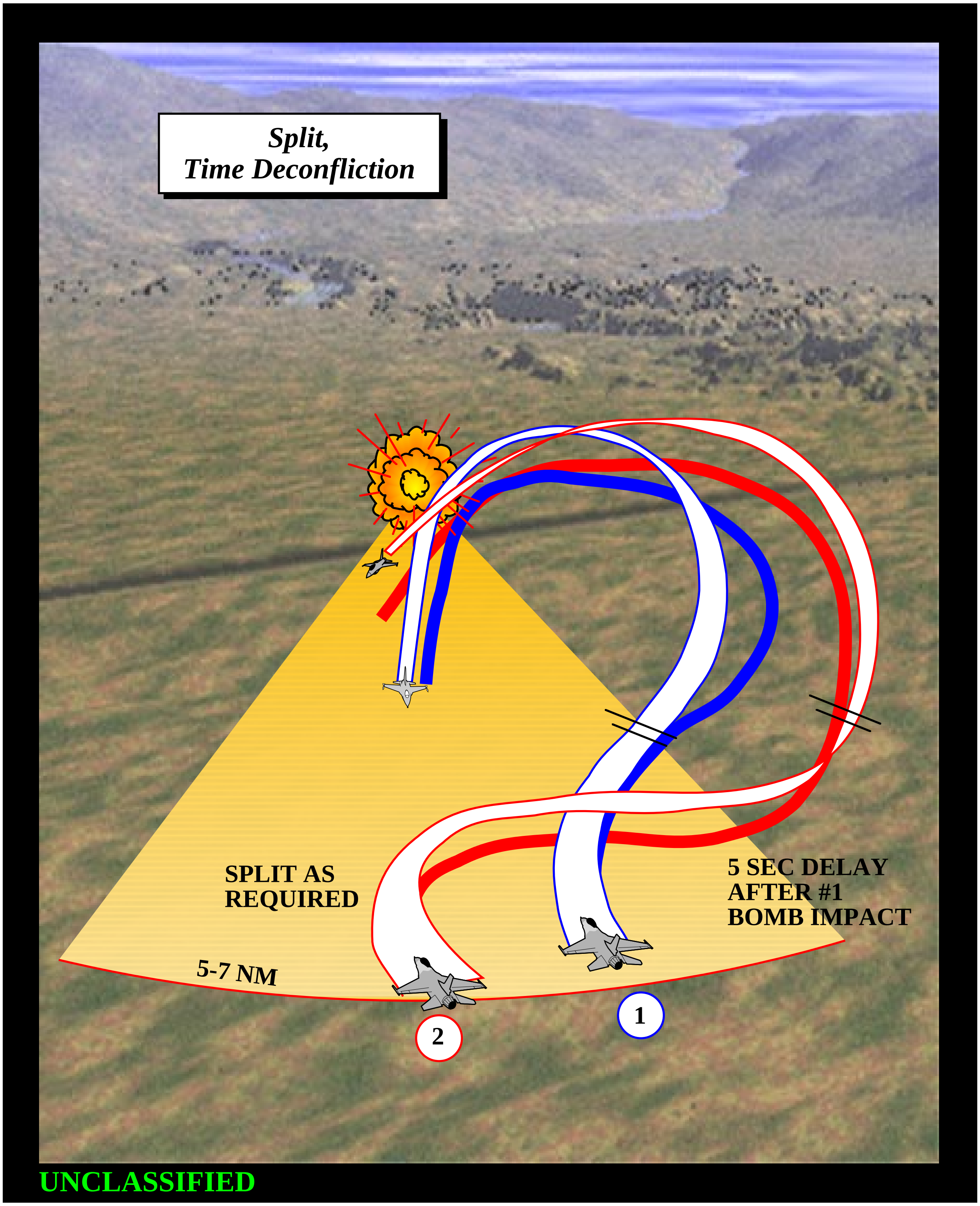


Figure 5.51. Echelon, Altitude Deconfliction.

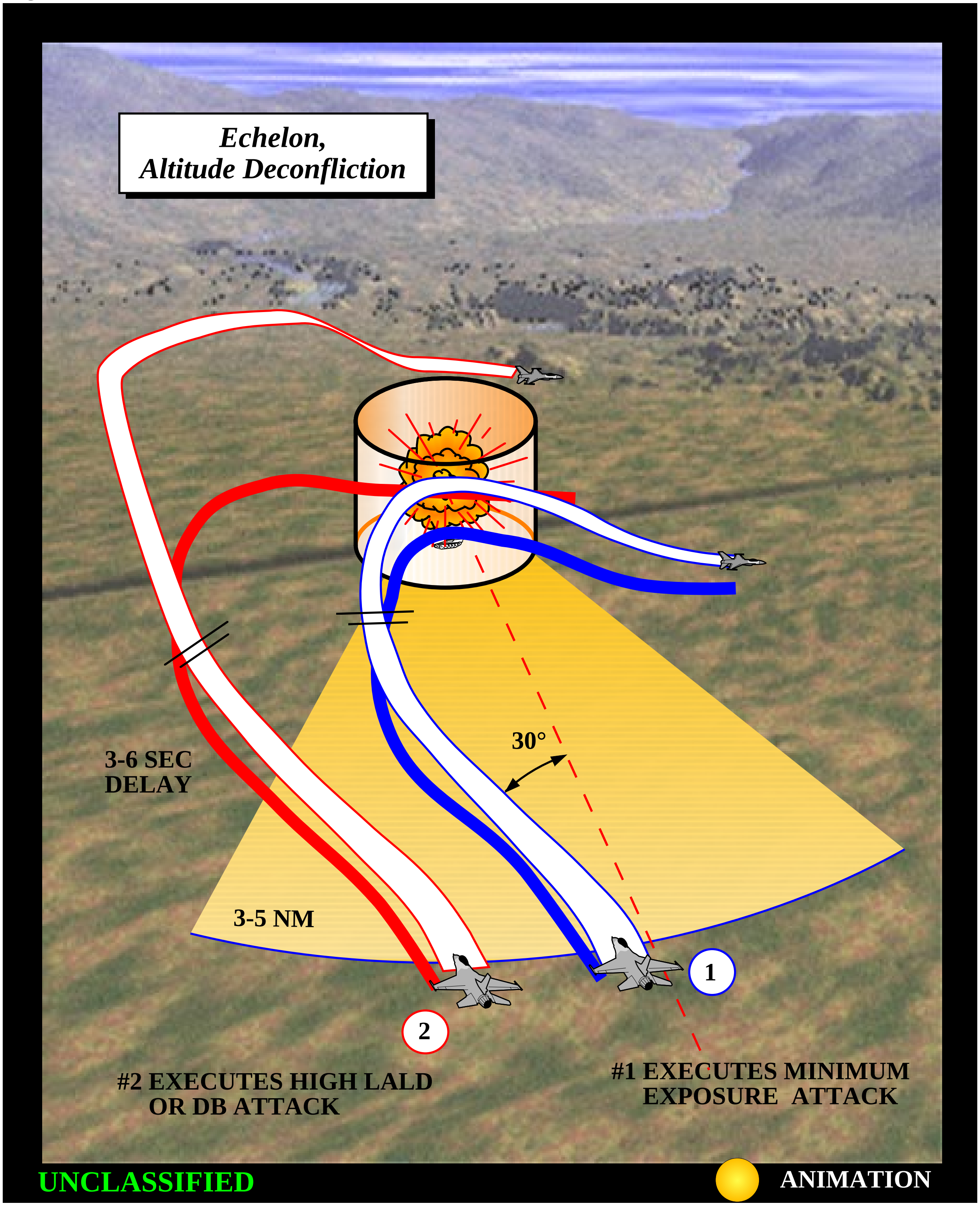


Figure 5.52. Echelon, Time Deconfliction.

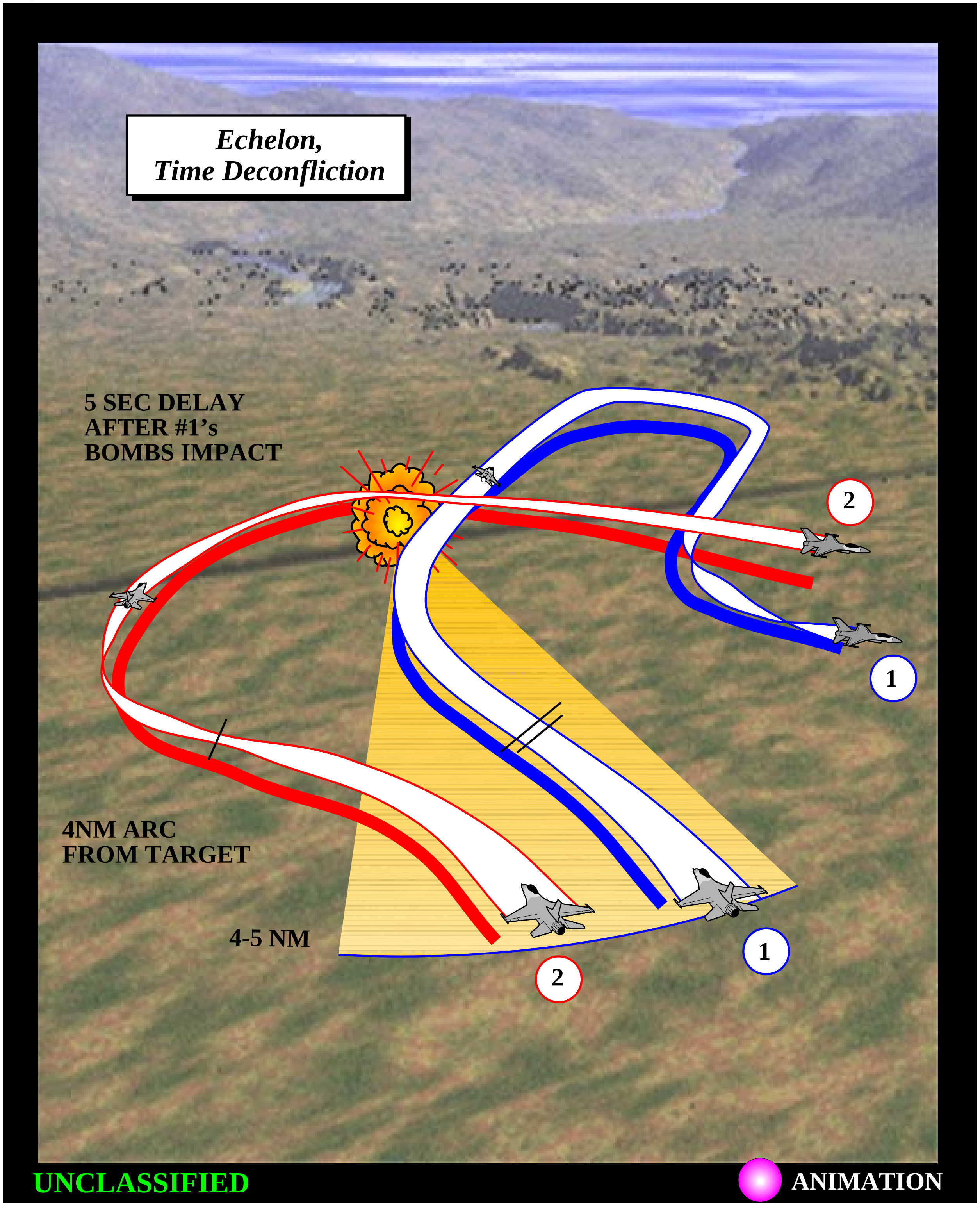
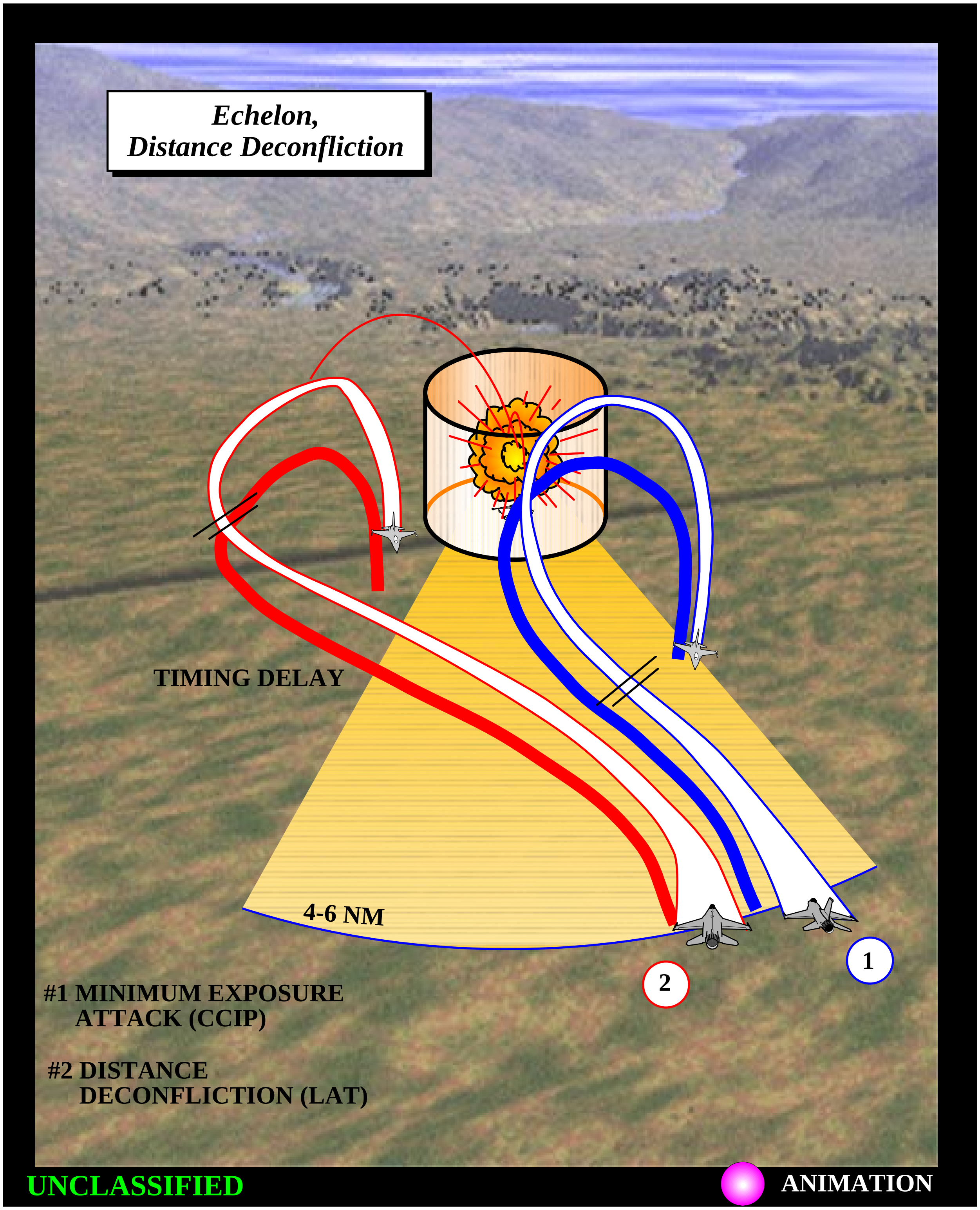


Figure 5.53. Echelon, Distance Deconfliction.



5.19.4. Time Deconfliction. As an example, as shown in **Figure 5.50.**, Split, Time Deconfliction, the second aircraft arcs at 4 to 5NM until the first aircraft's bombs explode, counts 5 seconds, turns to place the target at 10 or 2 o'clock, then executes a LALD, or VLD delivery to give approximately 30 seconds spacing. Timing deconfliction requires longer time in the target area than either distance or altitude deconfliction attacks. This technique should only be used for a single point target where accuracy is important and weather forces very low altitude attacks. There are many available techniques to gain time deconfliction.

5.19.5. Trail Attacks. A trail attack provides timing deconfliction but gives up visual support for the second aircraft during ingress. Trail formation can be achieved by a spacing maneuver such as a 90/90 or by airspeed. Both aircraft use deliveries such as VLD or loft that minimize exposure to the terminal threats. The first aircraft breaks away from the target after release with the second aircraft watching for SAM launches. To provide visual support for the second aircraft, the first aircraft turns back across the ingress heading. This helps to reacquire the second aircraft while beaming the threats. (See **Figure 5.54.**., Two-Ship Trail Attack.)

5.19.6. Shooter/Cover. The shooter cover option can be flown by a two-ship and allows one aircraft to attack the target using a preplanned profile. The second aircraft stays low and provides visual support by flying an arcing pattern outside the terminal threat. After the first aircraft has delivered ordnance, the second aircraft has the option of executing an attack, or egressing with the element mate (similar to the two-ship attack in **Figure 5.50.,** Split, Time Deconfliction.) This option is especially viable in a very high threat arena

5.19.6.1. The shooter's role is to find and destroy the target. If necessary, inform the cover aircraft on target specifics and egress intentions. The shooter should adjust any follow-on attacks based on first-look observations.

5.19.6.2. The cover role includes providing visual look-out for air and surface threats. The cover pilot may engage or suppress pop-up threats according to prebriefed criteria. The cover pilot must maintain overall battle SA while maintaining visual.

5.19.7. Loft Attacks. Loft deliveries allow weapons to be delivered simultaneously. In case of a degraded system aboard one aircraft, a loft can be made on the wing. Another option is the individual loft delivery.

5.19.7.1. Simultaneous Loft. Both aircraft loft the ordnance from wedge. The formation should be spread 6,000 to 9,000 feet to compensate for convergence during the loft maneuver. Prior to pull-up, the wingman centers up the computed steering displayed on the HUD. An immediate roll or dive recovery after weapon release is recommended. Avoid a perfect 180-degree reversal as this would ease the tracking solution for ground threat systems. (See **Figure 5.55.,** Simultaneous Loft.)

5.19.7.1.1. Advantages:

- The laterally spread formation causes confusion for ground threats.
- Provides stand-off from target area threats.
- Each F-16 has independent loft accuracy.
- Egress formation can be established quickly.

5.19.7.1.2. Disadvantages:

- Accurate deliveries may not be possible.
- Target coordinates may not be accurate.
- No good against mobile targets.
- Requires accurate system.
- Relatively good weather is necessary to maintain visual formation during pull.
- Mutual support is limited during the loft maneuver.

5.19.7.2. Loft on the Wing. One aircraft may be required to bomb using the computed solution of the other aircraft due to system malfunction or weather constraints. In this case, the wingman flies within 500 feet of the lead aircraft, matches the pitch rate during the pull-up, and manually releases weapons in sequence with the leader's release.

5.19.7.3. Trail Loft. The wingman is positioned approximately 3 NM in trail. This distance puts ordnance on target for a longer time period and reduces the potential for conflict between the leader's egress maneuver and the wingman's loft maneuver. Lead should call the direction of break off after delivery if this has not been prebriefed.

5.19.7.3.1. Advantages:

- Individual aircraft are free to maneuver during ingress and egress.
- Individual system accuracy increases the total mission probability of kill (P_k).

5.19.7.3.2. Disadvantages:

- Both aircraft must have full-up systems.
- Mutual support between aircraft is limited.
- Rejoin off target is difficult.

5.19.7.4. Aircraft and Ordnance Deconfliction. Consideration must be given for deconfliction from lofted bombs during their TOF.

5.19.7.4.1. For element lofts, it is critical that the wingman not fly further forward than wedge and the leader must turn away from the wingman during the egress turn. Failure to do so could result in the leader having a mid-air with the wingman's bombs.

5.19.7.4.2. For single-ship loft, following release, maneuver away from the bomb's trajectory. Maintain this lateral separation. There have been cases where after release, aircraft have turned back toward the target area and subsequently had a mid-air with their own lofted bombs.

5.20. Egress. The target area egress plan must be flexible, simple, and fully understood by all flight members. Reasons for egress and abort are:

Figure 5.54. Two-Ship Trail Attack.

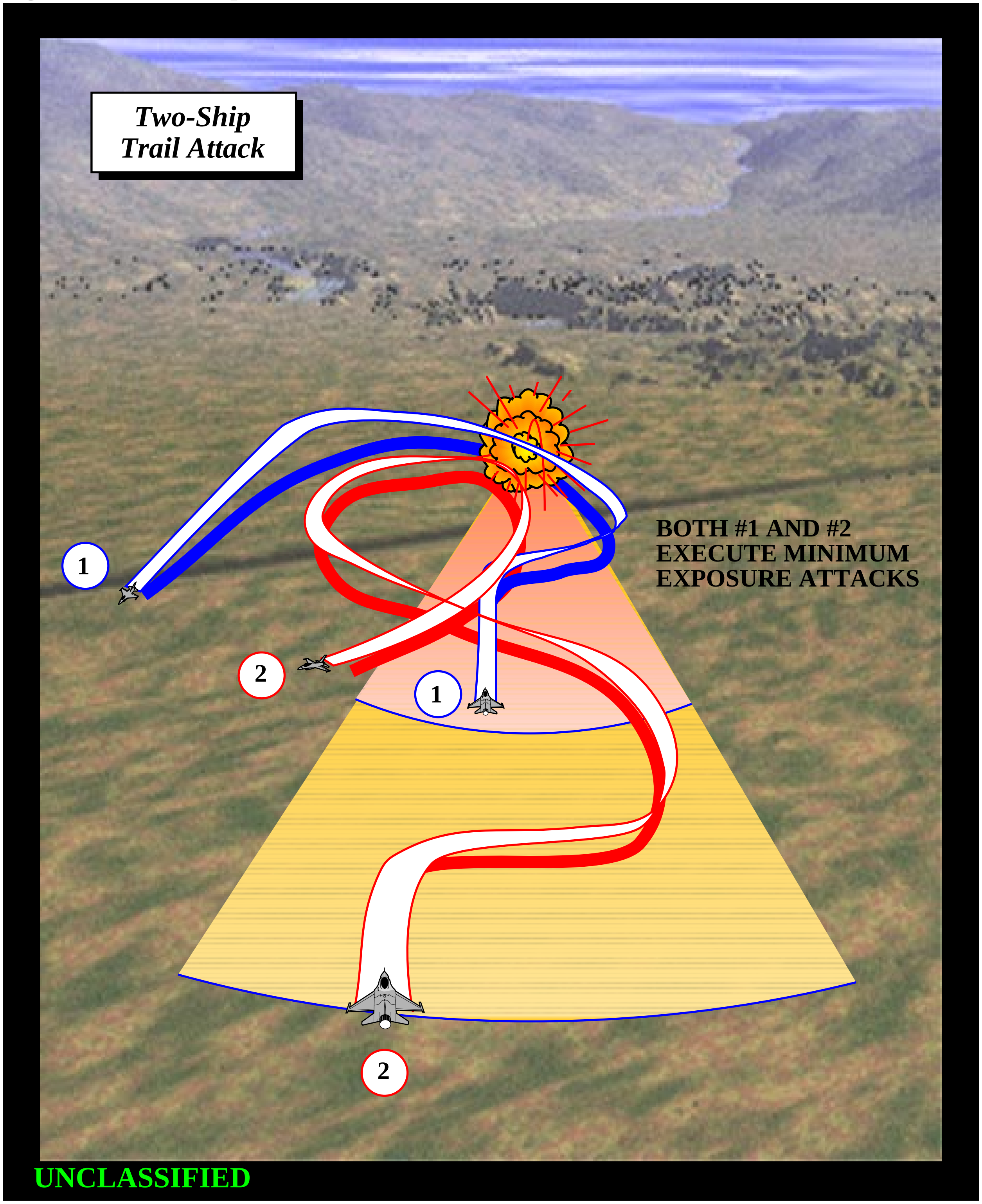
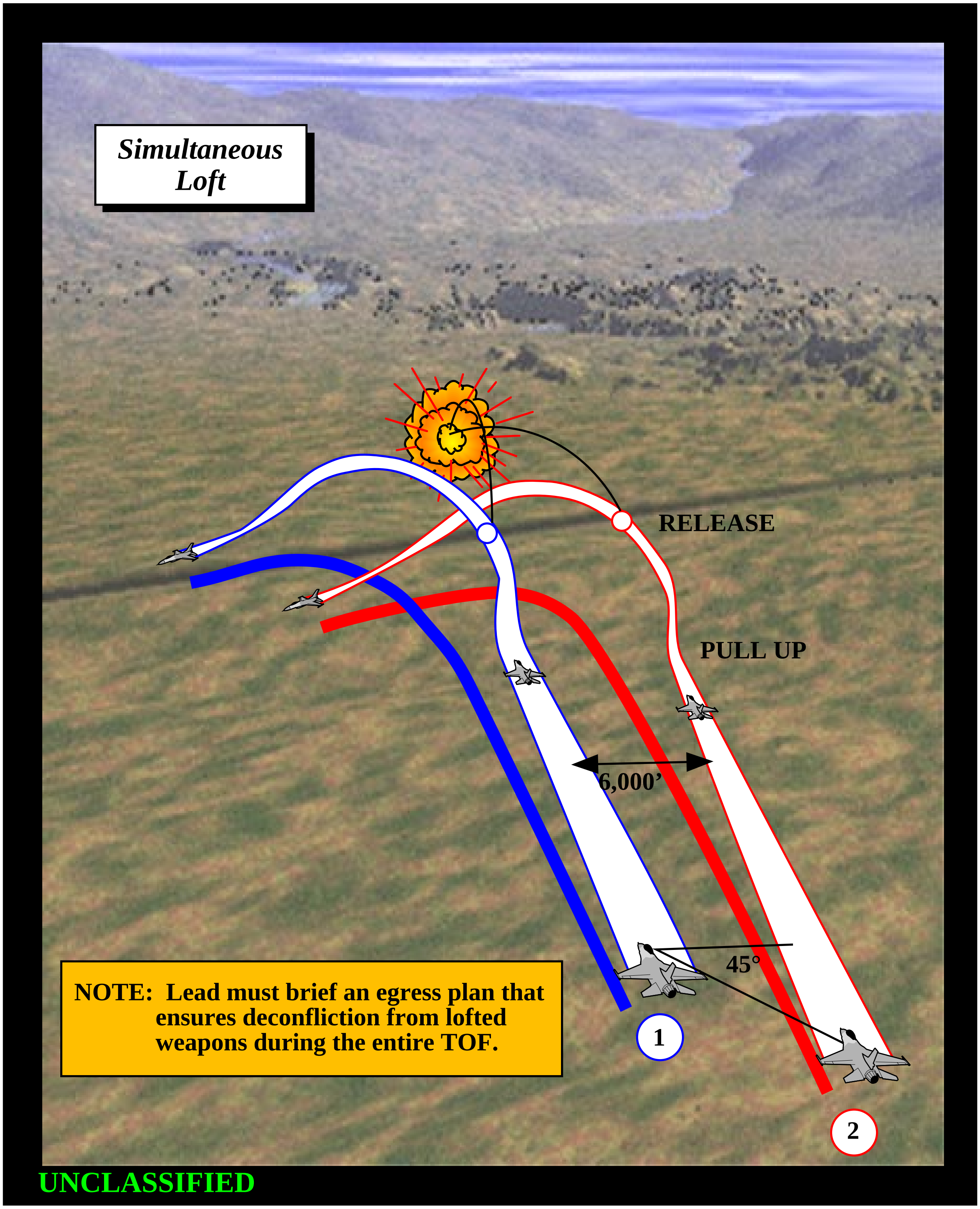


Figure 5.55. Simultaneous Loft.



- Target destruction.
- Poor weather.
- Unacceptable target area defenses.
- Low fuel.
- Loss of mutual support.
- Loss of required aircraft systems.
- Target acquisition problems.
- Battle damage.

5.20.1. Egress Priorities. Egress priorities should be based on target area threat (type, intensity, lethality), weather, follow-on attacks, status of follow-on attackers (engaged/ offensive/defensive/ neutral). General priorities are:

- Leave target area.
- Get away from threat envelope.
- Regain mutual support.

5.20.2. Blind or Separated. If a pilot becomes separated from the flight, follow the egress plan and provide your own threat lookout while proceeding to the prebriefed tactical rendezvous point. This point should be relatively free of defenses, allow for battle damage checks, and provide possible initiation of a reattack. Most importantly, join with someone as soon as possible.

5.20.3. Two-Ship Egress. Following ordnance delivery, both aircraft should turn toward their prebriefed egress heading. Line Abreast formation provides the most effective defensive lookout. However, it may be impractical to maneuver in the immediate target area to gain a line abreast position due to target area defenses. Therefore, adhere to the egress game plan with an accepted loss of visual cross coverage. A weave back to line abreast is advised when tactically acceptable.

5.20.4. Three-Ship Egress. If a three-ship is employed in the target area, the first aircraft off the target should turn the shortest direction to the egress heading and provide own lookout. The two-ship element provides its own threat detection and maneuvers to cover the first aircraft's 6 o'clock when possible.

5.20.5. Four-Ship Egress. When a four-ship is employed in the target area, the elements will normally be separated by time or geographical reference within the target area for weapons deconfliction. They should maintain element integrity throughout the attack and egress as an element with visual mutual support. When clear of the target area, both elements should rejoin in an area relatively free of enemy defenses. Avoid excessive turning in the target area while attempting to rejoin a four-ship flight.

5.20.6. Egress Factors. The egress must be flexible, consider terrain, battle damage, communication, and flight responsibilities.

5.20.6.1. In mountainous terrain, an in-trail option may be appropriate to mask defenses. Flat terrain allows for good visual cross coverage while using a Line Abreast formation to provide threat warning.

5.20.6.2. Perform a battle damage check on each flight member.

5.20.6.3. Perform “wounded bird” procedures when egress cannot be flown at the prebriefed airspeed. If the aircraft is flyable, initiate egress immediately. Prior to the forward edge of the battle area (FEBA), return to base (RTB). Past the FEBA, if unable to cross back over the FEBA, ejection in the safe areas should be considered. If unable to cross, initiate “wounded bird” procedures.

5.20.6.4. Pilots should be prepared to fly the entire egress plan without radios due to the possibility of communication jamming and to keep the frequency clear for other aircraft. Visual is assumed unless wingmen make a blind call. Adhere to prebriefed flight paths and visual signals to reduce confusion during egress.

5.21. Wounded Bird. The first priority for the wounded bird's pilot is to communicate the aircraft's status. If the level of damage is severe and the enemy threat is high enough to greatly endanger escort aircraft, the decision may have to be made to leave the battle damaged aircraft on its own to preclude further and unnecessary losses.

5.21.1. Escort Actions. If the effected aircraft can maintain a minimum of 400 knots (or 0.8M at high altitude), then it can be escorted in a standard formation, even though the escort aircraft will have to throttle back. The escort aircraft and the damaged aircraft should clean off any nonessential drag. If the damaged aircraft cannot maintain minimum speed, then the supporting aircraft will have to stand off from the damaged aircraft in a position from which the 6 o'clock can be protected. Weaves of 30 to 45 degrees for the egress heading will allow the supporting aircraft to maintain a minimum of 400 knots while maintaining a protective position on the slow aircraft. Using 400 knots and a 45-degree weave means that the escorted aircraft is flying at only 280 knots. Weaves up to 60 degrees will allow escort of a 200-knot aircraft. Weaves can be disorienting and may highlight the escort and/or the wounded bird. Another pattern option is for the escort to fly a racetrack offset from the wounded bird, on course. This pattern allows the escort to look both at the wounded bird's 6 and 12 o'clock while giving the escort time to visually reacquire and check the wounded bird’s progress. If the damaged aircraft has avionics, the pilot can assume the navigation and radar search responsibilities. This allows the protector to concentrate on visual lookout for both aircraft. Offensive commit criteria will be more constrained than normal On the commit, the escort will take the lead in the acceleration maneuver and merge with bandits first. The damaged aircraft should use avionics and/or descriptive commentary to get a tally and possibly some ordnance in the air after it has a positive identification from the escort (engaged) fighter.

5.21.2. Engagements and Threats. If at any time during the egress, an active engagement ensues and a bandit approaches ordnance parameters on the damaged aircraft, the pilot must make the decision either to try a last-ditch maneuver, or to eject. If the capability exists to spoil an attempted gunshot, the pilot should direct that move above the horizon in order to preserve altitude for a safe ejection.

5.21.3. Two-Ship Escort. In a three-ship formation with a slow, damaged aircraft, firepower is improved, but the escorting pattern is more complicated. Weaving behind a slow aircraft as a two-ship may do more to attract a bandit's attention. A close-tied racetrack pattern around the damaged aircraft using radars to sanitize the 6 and 12 o'clock avenues of approach may be effective.

5.21.4. Three-Ship Escort. In a four-ship, consideration should be given to the threat arena, ordnance, and fuel available. Although you should never jeopardize all four to save one, the healthy element could be used to sweep for the damaged aircraft while element mate escorts.

5.21.5. FEBA Crossing. As the flight approaches the FEBA or any heavily defended surface-to-air arena, the healthy aircraft must accelerate to penetrate the defenses. If it is any consolation, the pilot of the disabled aircraft can observe the active threats as they attempt to engage the other flight members. This will allow course changes to make the aircraft less vulnerable to the observed threats.

5.21.6. Friendly Airspace. Once across the FEBA, the flight member should orbit to pick up the damaged aircraft. The enemy's air order of battle (AOB) is still a threat, so “wounded bird” procedures must continue. Close to the landing base, appropriate emergency procedures should be accomplished.

5.22. Recovery. Recovery options should be based on factors such as fuel, safe passage procedures, and threat detection.

5.22.1. Fuel. Fuel is a primary concern on recovery. The engagement of an unexpected threat during egress may result in a fuel state that makes recovery to the primary base impossible. Pilots must have preplanned bingos during the entire recovery profile; know when to climb, when to divert, and when to jettison external tanks or suspension equipment in order to increase range.

5.22.2. Safe Passage. These procedures differ by theater. Knowledge of recovery options is mandatory. Inoperative identification, friend or foe (IFF)/selective identification feature (SIF) equipment, radio out, etc., may force rendezvous with other friendly aircraft for recovery.

5.22.3. Ground Threat at Recovery Base. Manportable SAMs and small arms pose a potential threat during departures and recoveries.

5.22.4. Departure. Fly departures IAW local procedures and directives. As applicable, minimize use of afterburner and arm flares. Fly an unpredictable flight path when safely airborne.

5.22.5. Recovery. Fly recoveries IAW local procedures and directives. If applicable, arrive on initial with 400 knots in Line Abreast formation. If straight-in approaches are directed, offset the aircraft in front as much as possible.

5.22.6. Landing. After landing, the compromise between force protection (sheltering of aircraft) and combat turnaround needs to be considered. Also, decontamination procedures may be in effect upon landing.

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CHAPTER 6

AIR REFUELING

6.1. Introduction. When basic information is mastered, air refueling (AR) in the F-16 is relatively easy; it is very similar to Close Trail formation. The aircraft is stable on the boom, there is plenty of excess power available, and the visibility is exceptional. An in-depth knowledge of procedures is essential for safe and efficient AR. Most of these procedures are presented in this manual. Refer to TO 1-1C-1, *Basic Flight Crew Air Refueling Manual* and TO 1-1C-1-30, *F-16 Flight Crew Air Refueling Procedures with KC-135 and KC-10*, for a detailed explanation of procedures.

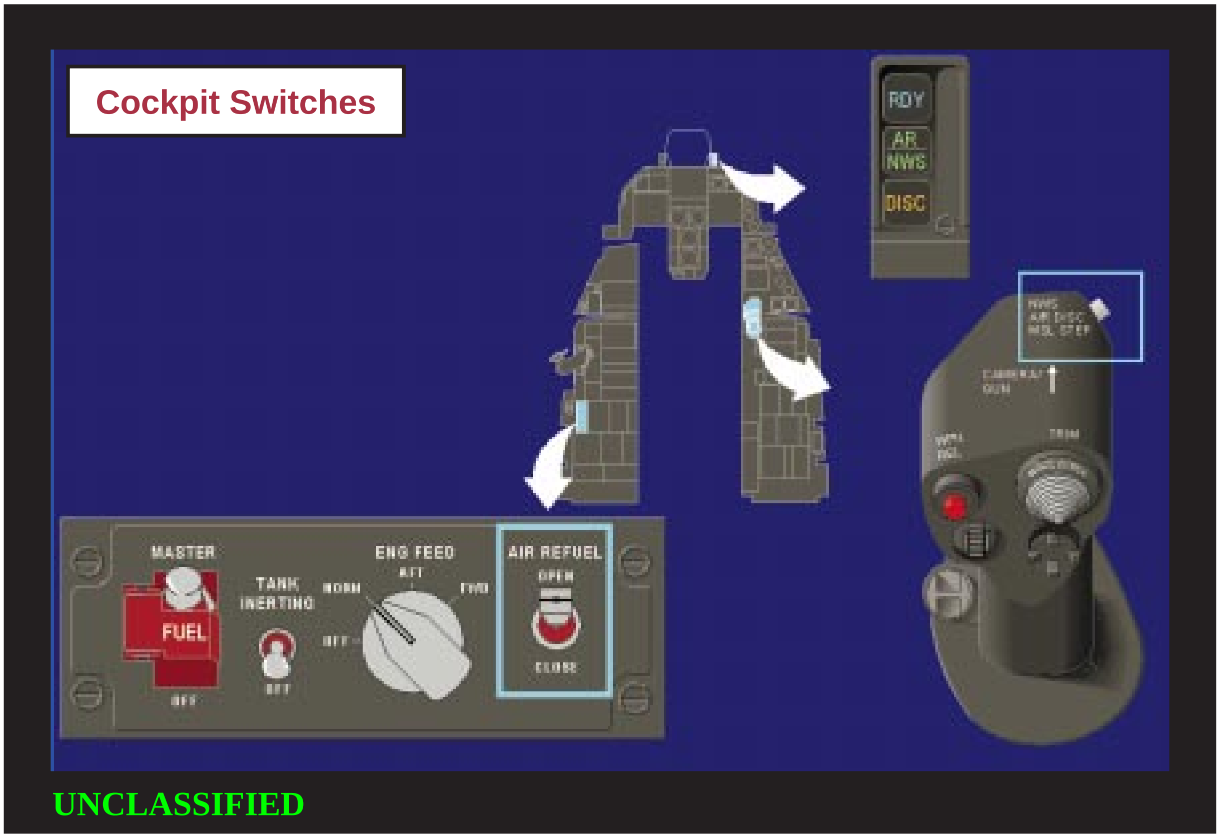
6.2. Mission Preparation. Prior to the briefing, review AR procedures in current TO guidance. AR terms are defined in TO 1-1C-1. Obtain the AR information including tanker call sign, refueling track, refueling altitude block, fuel offload, refueling frequencies, air-to-air tactical air navigation (A/A TACAN) channel, and air refueling control time (ARCT). Determine the forecast weather for rendezvous and refueling. ***NOTE:*** The position, coordinates, and TACAN fixes associated with the air refueling initial point (ARIP) and the air refueling control point (ARCP), can be found in FLIP AP/1B.

6.3. Ground Operations. During normal after-start checks, check the AR system. Move the AR switch to the OPEN position and check the AR status lights for a blue RDY light on and the DISC light off. Depress the AR/NWS DISC on the side stick and check that the amber DISC light is on. Three seconds later, the RDY light should come back on and the DISC light should go out. Move the AR switch to CLOSE and check that the RDY light extinguishes. The crew chief will confirm operation of the AR door and slipway lights. Confirm that the slipway lights are also turned up to illuminate the refueling receptacle (**Figure 6.1.**, Cockpit Switches). ***CAUTION:*** On the ground, depressing the AR/NWS button cycles the NWS. After closing the AR switch, check NWS light on prior to taxiing.

6.4. En Route. There are several different techniques for setting up the radar to search for the tanker. A common technique is to select 80 NM range, and 2-bar, with the acquisition symbols initially positioned at 50 percent scope, elevation set to bracket the tanker's expected altitude. The steerpoint should correspond with either the ARIP or ARCP. If bullseye will be referenced, ensure it is selected. Use A/A TACAN to receive the range to the tanker. Ensure the Master Arm switch is in SAFE.

6.5. Rendezvous. Point parallel and fighter turn-on are tanker rendezvous methods. The point parallel is normally used any time the tanker has no aircraft currently rejoined (“chicks in tow”), and the tanker positions at the ARCP. The fighter turn on is generally used when there are several flights scheduled for the same tanker, and one flight is joined as the next flight begins its rendezvous, or when the tanker is in an anchor pattern. Brief and use ground-controlled intercept (GCI) to the maximum extent, but monitor the intercept geometry to ensure an efficient rendezvous. Use the inertial navigation system (INS), radar, and A/A TACAN to monitor the rendezvous. Visualize the rendezvous geometry to detect deviations as they develop (e.g., insufficient lateral separation or excessive heading crossing angle [HCA]). Ensure altitude separation with the tanker is maintained until visual contact is established. Complete the armament safety check prior to putting the tanker in a weapons employment zone (WEZ).

Figure 6.1. Cockpit Switches.



6.5.1. Point Parallel. Radio contact will be established with the tanker prior to arriving at the ARIP. Emission Control (EMCON) Option 2 will be used as the normal AR communication procedure IAW TO 1-1C-1-30. If both the tanker and receivers are on a common GCI/ATC frequency to obtain ground rendezvous assistance, the change to the AR frequency may be delayed until positive radar/visual contact is established. If under radar control, obtain bearing and distance to the tanker prior to changing to the AR frequency. As soon as reliable radio contact has been established with the tanker, position information from a common TACAN may be exchanged (if available). GCI/ATC or the tanker should clear the flight to depart the ARIP. Maintain 1,000 feet below the tanker until visual contact is made with the tanker.

6.5.2. Rendezvous Options. Proceed from the ARIP to the ARCP using all aids necessary to maintain track course. Range information to the tanker is available from A/A TACAN or ATC/GCI. One flight member (normally the lead) will set the assigned A/A TACAN prior to departing the ARIP. All flight members will monitor the rendezvous with onboard radars. If the rendezvous is proceeding properly, lead should call the tanker's turn to refueling heading at 26 degrees azimuth and 21 NM range, with 180 degrees HCA. Radar display progression is depicted in Figure 6.2., Rendezvous Options. The terminal stage of the rendezvous is critical. The point parallel rendezvous will result with the tanker 3 NM in front of the fighters. If the tanker turns too late or too slowly, an overshoot may develop. If the tanker turns early or with higher rate, a “cold” rollout (the tanker more than 3 NM ahead) results. During the turn, the tanker should be 45 degrees left at 13 NM with 90 degrees HCA, and 34 degrees left at 8 NM. If the range is less at either point, reduce speed to 300 KCAS and advise the tanker to “PUSH

IT UP." A slight turn away from the tanker will also preserve range. If range is greater at a point, increase speed (350 KCAS) and turn slightly into the tanker. Be aware that the radar may enter the coast mode or break lock at 90 AA. In visual meteorological conditions (VMC), visual with the tanker is normally acquired before this point. If not, maintain heading and altitude while attempting to reacquire. The checkpoints are based on the following conditions:

- Speed: tanker 260 KCAS, fighter 310 KCAS.
- Altitude: FL 250 to 300.
- As a rule of thumb, accelerating to 350 KCAS as the tanker starts the turn, decreases roll-out range by 2 NM, thus allowing the fighters to roll out 1 NM behind the tanker.
- Ensure altitude separation until established behind the tanker with visual contact. AR airspeed is 310 KCAS; the tanker will maintain 260 KCAS until the receiver "PUSH IT UP" call.

6.5.3. Fighter Turn-on. Although you may use normal intercept techniques for a fighter turn-on rendezvous, these steps allow for a controlled rejoin, normal for ATC operations or while in instrument meteorological conditions (IMC):

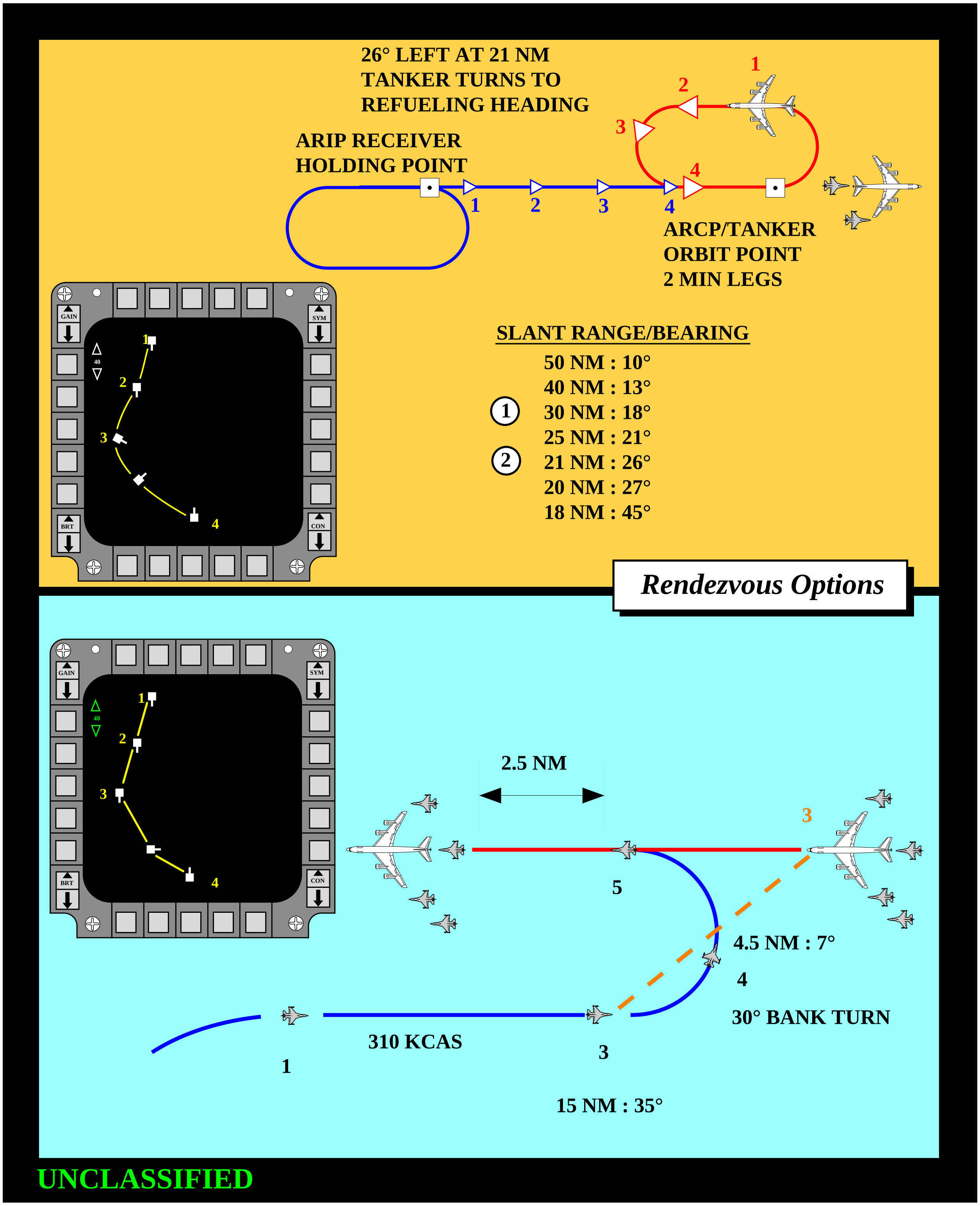
- The fighters turn instead of the tanker, using 30 degrees of bank, and maintain 350 KCAS throughout the rendezvous until the closure rate dictates an airspeed adjustment.
- The fighters start the conversion when the tanker is at 35 degrees relative bearing and 15 NM range.

6.5.4. The tanker should be at 7 degrees relative bearing and 4.5 NM when the fighters are halfway through the turn. The tanker will establish refueling airspeed when requested by the flight lead. The fighters will adjust airspeed as needed to achieve the desired closure rate. At the completion of this turn, the fighters will normally arrive in 2.5 NM trail. Be aware that the radar may enter coast mode or break lock. React in the same manner as the point parallel while maintaining 30 degrees bank.

6.5.5. Use caution during the rendezvous, confirm the radar continues to track the tanker. It may transfer to the flight on the tanker as they depart. Be alert for maneuvers that do not match the expected tanker track—if in doubt, query the tanker. Also, compare radar range with A/A TACAN range.

6.6. Rendezvous Overrun. When a rendezvous overrun occurs, the tanker or receiver pilot will immediately transmit a warning to all flight members and initiate rendezvous overrun procedures. In the event of an overrun, the receivers will pass 1,000 feet below the tanker to ensure positive vertical separation. The receivers will decelerate to 290 KCAS and maintain AR heading. The tanker will accelerate to 355 KIAS or Mach 0.90, whichever is lower, and maintain AR heading. When the receiver regains 3/9 line and visual with the tanker, the receiver pilot will slow the tanker and complete the rejoin. The tanker will decelerate to AR airspeed and normal closure procedures will be employed to establish contact.

Figure 6.2. Rendezvous Options.



6.7. Observation Position. As the flight approaches the tanker, the lead should direct a channel change to “boom” frequency. After check in, the boom operator may initiate a radio check which must be acknowledged by all flight members. Wingmen move to the observation position when cleared by the lead. This position allows the aircraft in the refueling position freedom of movement to the contact position. Receivers in the observation position will maintain a position slightly behind the tanker wing and one F-16 wing span clearance laterally, unless in-flight refueling (IFR) or night operations require less spacing. For a reference, align the tanker wingtip light with the fuselage window aft of the wing root. Stack vertically so the opposite wing and the outside engine root is visible above the tanker's fuselage. This should put the top of the tanker's tail on the horizon (**Figure 6.3.**, Observation Positions).

6.8. Prerefueling Checks. Follow procedures detailed in the checklist. Ensure all ordnance is safe and aircraft systems which emit electrical signals (TACAN, IFF, RADAR, ECM) are in standby. If carrying external tanks, the AR door should be opened 3 to 5 minutes prior to commencing refueling, so they can depressurize and be filled. Center line tanks frequently may not completely fill, regardless of depressurization time. Flight control gains change, but only slight trim adjustments may be required. Check for a blue RDY light and await clearance to the precontact position. Listen to lead's radio calls and be prepared to copy them.

6.9. Precontact Position. When the contact position is clear, and either the boom operator clears you or EMCON flow was briefed, reduce power slightly to move the aircraft back and down to the precontact position. Stabilize in a position approximately 50 feet behind (one-half to one ship length) and slightly (1 to 2 feet) below the boom. A common error is to slowly drift too far aft or be too low. Relax! Stabilize! Notify the boomer you are ready by calling "CALL SIGN, STABILIZED and READY." Stay in the precontact position until cleared by the boomer to move into contact. The boom operator will then clear you into the contact position on the radio, or by a steady "F" light (EMCON). Acknowledge and advance power slightly to ease forward (**Figure 6.4.**, Precontact Position).

6.10. Contact Position. Movement in the vicinity of the boom must be smooth and deliberate. From the precontact position, add only a small amount of power and wait for that power change to move you forward. As you move forward, bring the receiver director lights into your field of view (FOV). A steady light means a large correction is required and a blinking light means a small correction is required. As you slowly (1 to 2 knots) move forward, offset the boom slightly (2 to 3 feet) left or right, and maintain the slightly low position. As the boom approaches your canopy, it should pass 2 to 3 feet next to your head. As the boom passes out of your FOV, continue to move slowly forward and align the aircraft with the painted lateral reference line on the bottom of the tanker. Approaching the desired contact position, the boomer will call "STABILIZE" or the director lights may extinguish or start blinking (EMCON). Since your rate of closure has been small, a very small reduction in power is all that is required. ***NOTE:*** Common errors include: maintaining the tanker's same relative size after passing the boom (this causes the aircraft to drop low). Making large power corrections and/or moving too fast (this causes either "charging" the boom or falling out of the contact position). Once the boomer has plugged into you, the receiver director lights function, the blue RDY light on the indexer extinguishes, and the green AR/NWS light illuminates. Many tankers are configured for communication through the boom, so be in HOT MIC with the volume turned up. If, after contact, the director lights fail to illuminate, disconnect and return to the precontact position. If the tanker crew cannot fix the problem, you may still refuel but should ask the boomer for verbal corrections.

Figure 6.3. Observation Positions.

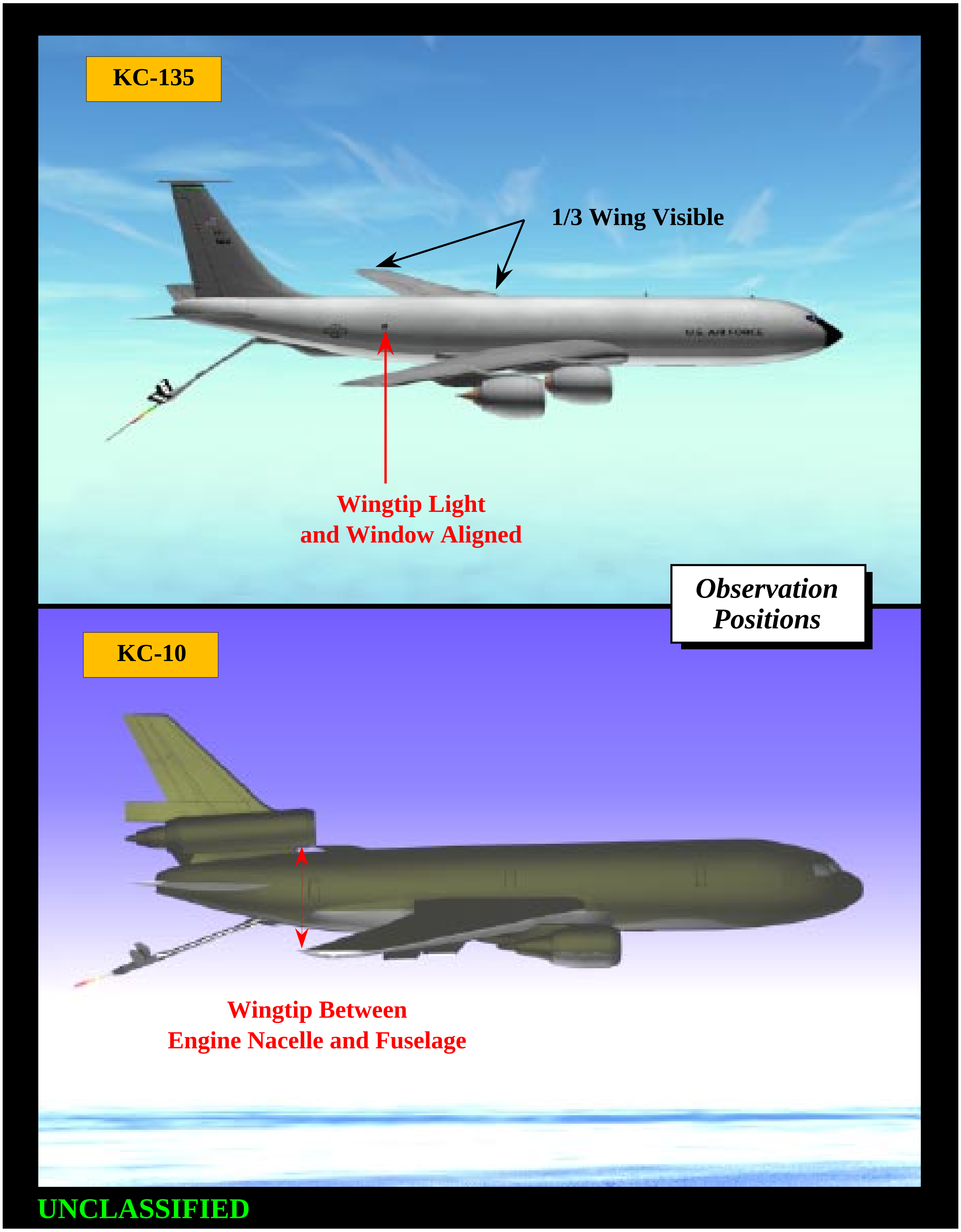


Figure 6.4. Precontact Position.

6.11. Maintaining Contact. After contact, continue to fly formation referencing the tanker director lights. It may be difficult to perceive small movements of your aircraft visually. The proper up-down and fore-aft position is indicated on the lights by the illumination of the center “captain's bars” on both columns of lights. If a light other than the “captain's bars” is illuminated on either column of lights, a correction is required. Mentally preface the D, F, U, and A lights with the word “GO,” and accomplish the move directed. (For example, GO “D”own or GO “A”ft.) To correct for position deviations, make small flight control and power changes. Do not delay these corrections, but make them smoothly and then wait to see the results of the correction—avoid over controlling. Maintain general position by visual reference to the tanker and refine position via the receiver director lights or the boomer verbally. In limited visibility, use the tanker as the attitude indicator while in the contact position (**Figure 6.5.**, Boom Envelope and Director Lights).

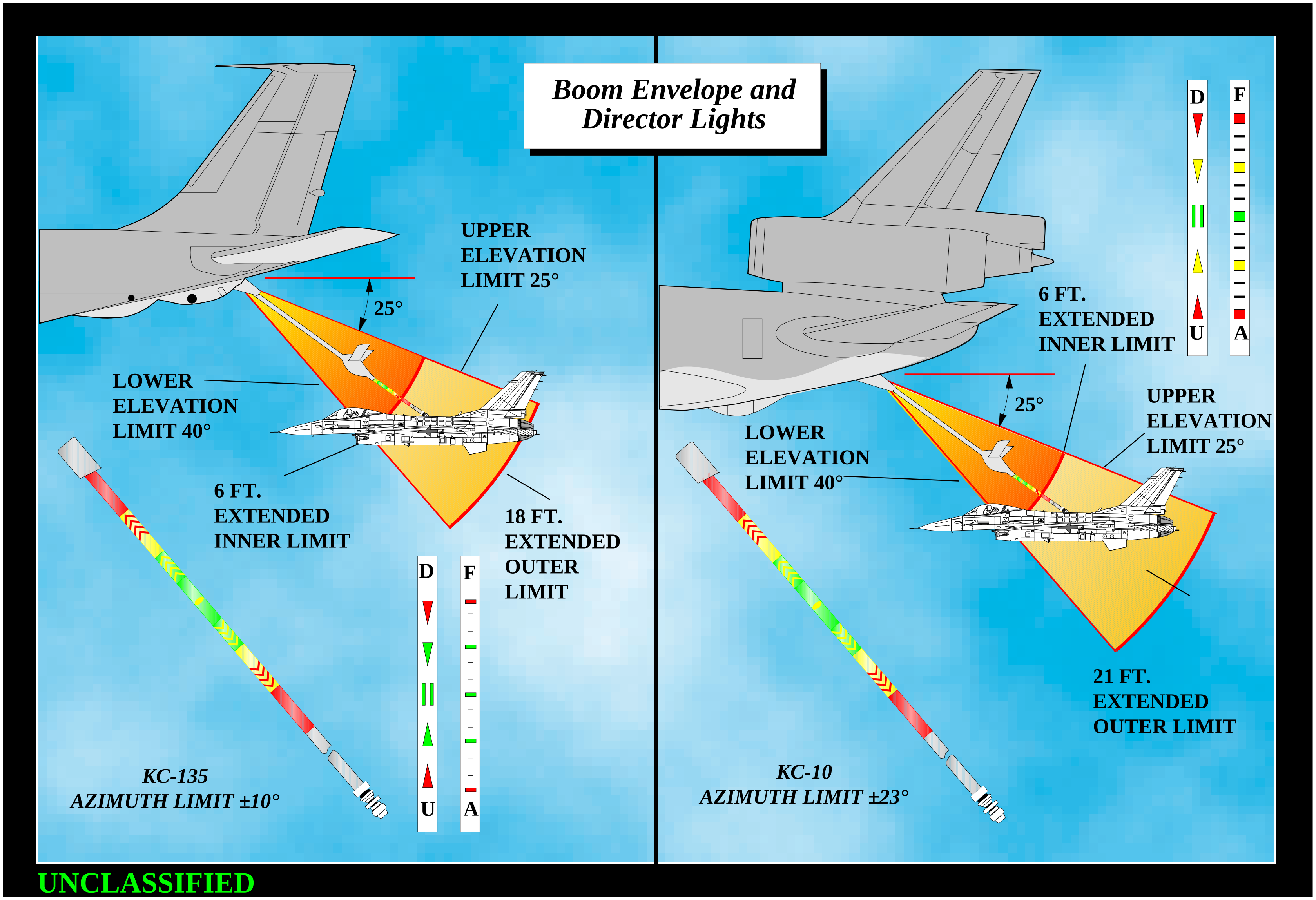
6.12. Position Indications. If you move out of position in only one direction, lights on both columns may change. For example, moving down, increases the boom angle and a GO UP indication will display. In addition, you may get a GO FORWARD indication because the pure downward movement has extended the boom. Understand this relationship when making corrections, e.g., if you have both the GO UP and GO FORWARD lights, you may only have to move up a little to extinguish both of them. KC-135 and KC-10 differences:

- The KC-135 lights only indicate position. You may be moving rapidly aft but when passing through the ideal position, both captain's bars will light.
- The KC-10, on the other hand, incorporates position and trend. In the same example, moving rapidly aft will produce a GO FORWARD command even when in ideal position. Thus, the KC-10 lights may seem a little more sensitive.
- The position of the KC-135 engines produce slight turbulence for an F-16 in an ideal contact position. This turbulence gets worse as the tanker increases its inboard engine power settings. So anticipate this turbulence, particularly at high altitude or with a tanker at high gross weight. This is not a problem with KC-10 tankers.

6.13. Disconnect. Disconnect if a trend toward any limit develops. If an unintentional disconnect occurs, follow tanker directions. Return to the precontact position, stabilize, and await clearance back to the contact position. Do not hesitate to initiate a disconnect at any time, especially if you feel safety-of-flight requires such action. If your F-16 approaches the upper boom limit on a KC-135, the boom could strike your aircraft. So, the upper limit for F-16 operations is 25 degrees. If you get high, the boomer will disconnect you before you see a red GO-DOWN indication.

6.13.1. Automatic Disconnect. The boom will automatically disconnect when the tanks are full (based on sensed overpressure). Centerline tanks frequently do not fill completely before automatic disconnect. Expect a tendency to move forward immediately after disconnect due to the sudden absence of boom pressure. Anticipate the automatic disconnect by monitoring fuel quantity and compensate for that tendency. If you do not get a top-off, the boomer will advise you when you have the briefed offload. At this time, initiate the disconnect. Most pilots will advise the boomer of disconnect by saying, “DISCONNECT NOW.” Remain in the contact position until the boom is clear. Both the receiver and the boom operator will acknowledge the disconnect.

Figure 6.5. Boom Envelope and Director Lights.



6.13.2. Disconnect Indications. After disconnect, the green AR/NWS disconnect light is extinguished and the amber DISC light illuminates. The AR system will automatically recycle itself, and the blue RDY light will again illuminate in approximately 3 seconds. Slide back to the precontact position. If no additional hookups are required, close the AR door and proceed as briefed or return to the observation position. Check fuel quantity prior to departing the tanker.

6.14. Air Refueling Emergency Procedures.

6.14.1. Breakaway. The breakaway is an emergency maneuver designed to ensure a separation between the receiver on the boom and the tanker. The tanker or receiver will initiate the breakaway by calling "TANKER C/S, BREAKAWAY, BREAKAWAY, BREAKAWAY" and flash all the director lights. Expect the tanker to increase power and initiate a slight climb when clear of the receiver.

6.14.1.1. Contact Position. If in the contact position, depress the AR disconnect, ensure the boom is clear, and reduce power to drop back and down until the entire tanker is in sight. Use speed brakes if necessary. Stay with the tanker unless another emergency dictates.

6.14.1.2. Observation Position. If in the observation position, stay on the tanker's wing. If a "BREAKAWAY" is called prior to any receiver reaching the observation position, the entire flight will stay together and not proceed to the precontact or observation positions.

6.14.2. Receiver Door Will Not Close. If the door will not close, normal flight control gains and tank pressurization will be gained with the AR switch in the CLOSE position. The RDY-AR/NWS-DISC lights may not indicate normally; and the NWS light will not illuminate when NWS is engaged.

6.14.3. Systems Malfunction. If any system malfunctions, or conditions exist which could jeopardize safety, AR will not be accomplished except during actual fuel emergencies. Any time receiver fuel venting is noticed, the boomer or other flight members will inform you. The flight lead retains the decision to continue. A small amount of fuel spray from the nozzle/ receptacle during fuel transfer is normal. Either the tanker or pilot experiencing difficulties can terminate refueling if required.

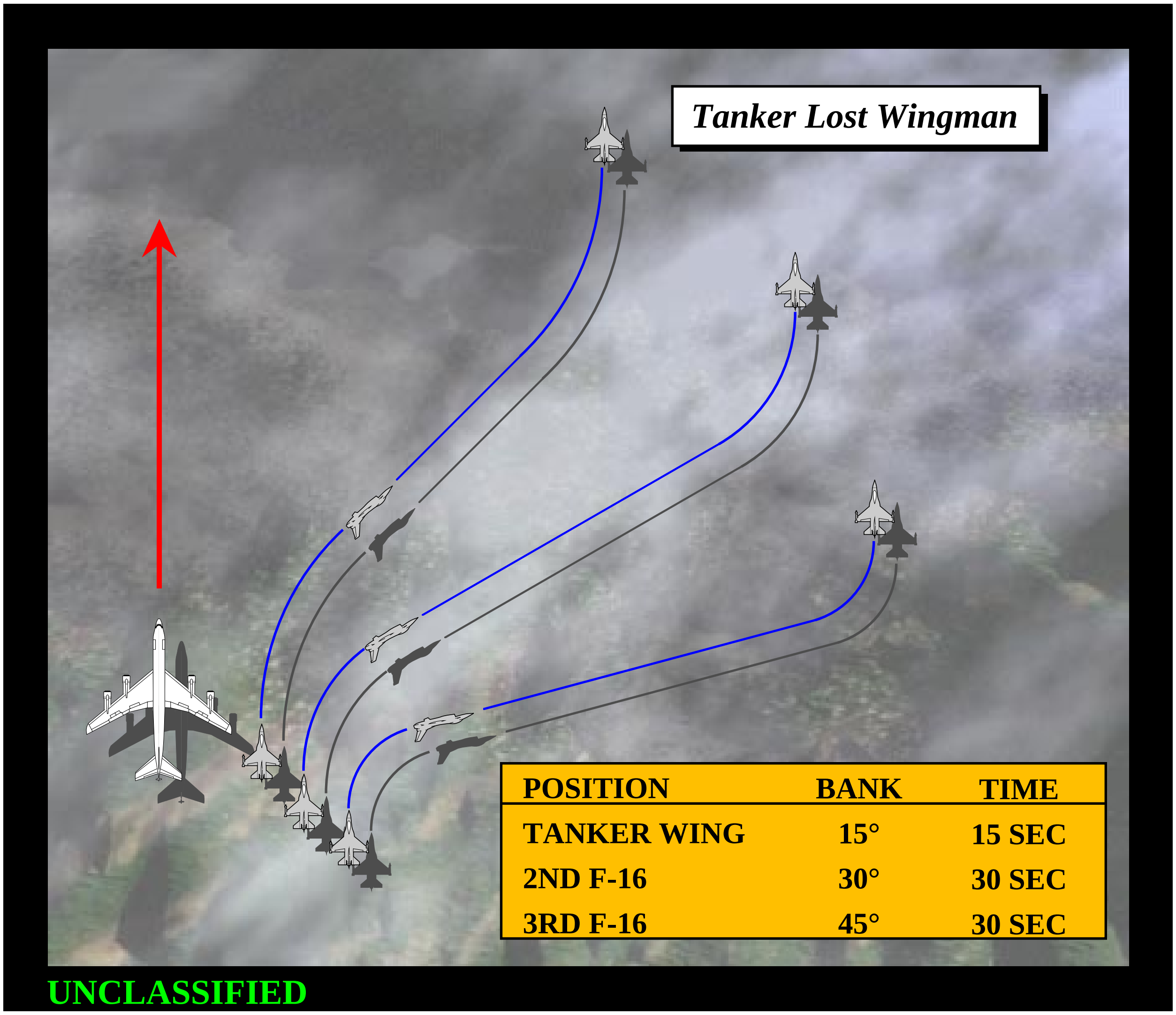
6.14.4. Manual Refueling. This mode of refueling will not be used in training, unless a fuel emergency exists. Manual refueling occurs when the tanker is unable to initiate a disconnect. The receiver must initiate all disconnects and remain particularly aware of the boom limits. Initiate a disconnect before arriving in position from which a safe disconnect cannot be accomplished.

6.14.5. Pressure Refueling. The tanker uses this emergency refueling procedure when all other means of fuel transfer has failed and a fuel emergency exists. The boomer will keep positive boom pressure on the receptacle so the fighter may require unusual stick inputs to maintain position. Because of the boom pressure, the disconnect is critical. The receiver and the boomer must coordinate it verbally.

6.14.6. NORDO Refueling. Refer to the current AR TO for tanker and receiver visual signals during NORDO refueling. NORDO refueling will only be used in an emergency situation.

6.14.7. Lost Wingman. Refer to **Figure 6.6.**, Tanker Lost Wingman, and TO 1-1C-1-30 for in-depth details.

Figure 6.6. Tanker Lost Wingman.



6.15. Post-refueling. Follow procedures detailed in the checklist. Do not change switches "heads down" when inside the precontact position. Verify the switch and door are closed before continuing with the mission. External fuel will not transfer with the AR switch in the OPEN position. Increased awareness of fuel distribution within the aircraft is imperative after AR. Fuel can fill external tanks before internal, and if not topped-off, may have to feed through the transfer system to be usable. External fuel will not transfer if the AR door switch is in the OPEN position.

6.16. After Landing. Perform a thorough postflight to assure aircraft was not damaged during refueling. This must include a visual check of the upper aircraft surfaces while exiting the cockpit or while on the ladder. Enter the offload data in the AFTO 781: Include tanker call sign, track designation, and fuel onload.

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CHAPTER 7

LOW-ALTITUDE OPERATIONS

7.1. Introduction. Low-altitude flight in rough terrain provides masking opportunities to degrade radar acquisition, limits visual detection, and contributes to tactical surprise. Properly executed terrain masking techniques make it difficult for threats to acquire the penetrating aircraft or its shadow. However, one should not fly lower than the threat, mission objectives, or comfort level dictates.

7.2. Low-Altitude Maps. Prepare maps IAW MCI 11-F16V3, *Pilot Operational Procedures—F-16* and MCR 55-125, *Preparation of Mission Planning Materials.*

- Highlight obstacles to the flight route such as towers and power lines.
- Annotate the minimum safe altitude (MSA) or route abort altitude (RAA).
- Determine planned fuel as well as continuation fuels at each point.

7.3. Low-Level Route Study. To ensure success in low-level missions, thoroughly study the route.

- Know how every major point will appear, either visually or on radar.
- Analyze the visual references to use in flight and points to avoid.
- Correlate point descriptions with visual expectations:
- Haze, smoke, dust, and fires.
- Sun position.
- Environmental variations (snow, leaves on trees, etc.).
- Also analyze the route;
- Predict expected radar use (air-to-air [A/A] versus air-to-ground [A/G]).
- Determine if deviations from course will be appropriate (masking, threats, etc.).
- Select update points (position and altitude).
- Review the altitude, restrictions, headings, and timing references.

7.4. Low-Altitude Awareness.

7.4.1. F-16AM Combined Altitude Radar Altimeter (CARA). The F-16AM CARA system can be used for altitude management during low-level operations. CARA is an aid to supplement visual capabilities and common sense. Ensure the system is on and set to the appropriate altitude IAW MCI 11-F16V3, *Pilot Operational Procedures —F-16*. Enter an altitude no lower than minimum approved altitude for day operations. Visual warnings are provided on the head-up display (HUD) and radar electro-optical (REO). Refer to the Dash 34 for more specific operating capabilities and limitations.

7.4.2. Low-Altitude Hazards. Be keenly and constantly aware of low-level hazards.

7.4.2.1. Visibility Restrictions, Visual Illusions, and Low Sun Angles. These can affect low-altitude perceptions. Terrain contours directly in front of you may be lost against the horizon. When in doubt, put the flight path marker (FPM) into “blue sky.”

7.4.2.2. Subtle Rises in Terrain. Maintaining level flight and a constant altitude may result in significantly reduced ground clearance. Constantly check NEAR ROCKS then FAR ROCKS.

7.4.2.3. Task Saturation/Fixation. The key to successful operation in the low-altitude environment is a solid cross-check, appropriate task prioritization, and situational awareness (SA). Cross-check should remain the same, only the time spent performing its various counterparts changes with altitude changes. Proper mission planning and selective use of low-altitude structure will help reduce the number of high task situations that occur while low.

7.4.2.4. Unperceived Descents, Overbanked Turns. Small descent angles or an unplanned increase in bank angles can result in significant descent rates and ground impact. Attention to the velocity vector (FPM) and altitude awareness cannot be overemphasized. Controlled flight into the ground is, in most cases, the result of misprioritization and task saturation. Regardless of assigned or perceived tasks, pilot distraction at low altitude is deadly. Refer to **Chapter 9** for low-altitude awareness exercises.

7.5. Low-Altitude Task Prioritization. Misplaced priorities occur when a task is accomplished at the wrong place or time. Operating at low altitude is a hazardous proposition; it significantly reduces the time available to divert attention away from basic aircraft control while handling other tasks. The danger of channelized attention and task saturation is diverting attention away from the pilot's first priority—***terrain avoidance — it is real and kills.***

7.5.1. Cockpit tasking varies at different times throughout a low-level route. It is important to re-establish priorities when mission tasking starts to override critical tasks. The following items illustrate techniques for minimizing low-altitude task saturation problems:

- Terrain clearance is the critical task and should be the first task performed. Climb to cope with high mission task loads.
- Accomplish avionics setup and checks as early in the flight profile as possible. Many avionics items can be set prior to takeoff, thus reducing work load at low altitude.
- Accomplish critical tasks first. Accomplish lesser tasks at lower cockpit tasking levels.
- Higher altitude allows less concentration on terrain avoidance and more time to accomplish other tasks. Flying below 500 feet is more demanding than above 1,000 feet.
- Pilots must be acutely aware of their flight path at all times. Head down avionics tasks are not appropriate if the aircraft is descending or turning.

7.5.2. Initial Descent. A particularly busy time during low-level flight is at the low-level start point. While descending and possibly turning, tasking may also include timing control, steerpoint selection, avionics updates, radar search, formation, and terrain avoidance. Problems can be insidious. Arrival at low altitude, with little or no warm-up, and then beginning the demanding work load required for low-altitude operations can be perilous.

Flight leads should consider accomplishing tasks prior to descending to their minimum altitude, or by delaying tasks until established on the route. The start route point should be planned so that reduced tasking is tactically feasible.

7.5.3. IP-to-Target. Another demanding time is during the approach to the target. Pilots must finalize attack avionics and switchology, sanitize the target area, and establish the briefed attack formation. Each pilot must continually anticipate situations of increased tasking and keep task priorities in order to accomplish the mission safely and effectively.

7.6. Low-Altitude Intercept Considerations. Low-altitude intercepts require special attention. Low-altitude considerations include the basic fighter maneuvers (BFM) concept of "turning room" required versus "turning room" available.

7.6.1. Turning Room. At higher altitudes, overshooting the bandit's flight path can result in a low energy/lag position in relation to the bandit. In contrast, overshooting a bandit during a high-to-low conversion can result in a collision with the ground. Prior to starting any conversion, confirm AGL altitude and turning room available. Plan for a conversion turn using both horizontal and vertical turning room for optimal performance. Limit bank angle to 135 degrees during the turn. Continue to assess altitude and ground clearance throughout the turn. If there are any doubts, reset the lift vector above the horizon and reduce the descent rate. If necessary, do not delay performing a high or low speed dive recovery.

7.6.2. Airspeed. Airspeed at low altitude is important due to increased aircraft performance and G sustainability. Higher energy states can be gained and sustained compared to higher altitudes. Aircraft turn rate and radius can be maintained in the optimal range for greater periods. For high-to-low conversions, a starting speed of 425 to 450 KCAS allows excellent turn performance and a high-energy state throughout the turn. For low-to-high conversions, a higher starting speed may be required (approximately 500 KCAS) to maintain optimal performance. Adjust power and use speed brakes to prevent exceeding optimal airspeed.

7.6.3. Avionics. Maximum attention must be dedicated to looking outside the aircraft during a conversion turn to ensure terrain avoidance and gain an early tally on the bandit. Expect missile WEZ volumes to be reduced at lower altitudes.

7.6.4. Ground Avoidance. Ground avoidance is the primary concern during high-to-low conversions. However, intercepts for low-to-high conversions also require emphasis on terrain avoidance and awareness, primarily during the intercept phase prior to the conversion turn. Closely monitor aircraft attitude and altitude; a shallow descent can lead to ground impact.

7.7. Low-Level Navigation.

7.7.1. Dead Reckoning. Dead reckoning (DR) is a basic method for navigation and is based on flying a precise heading, at a precise airspeed, for a precise amount of time. With F-16 avionics, DR is not required as the primary method for navigation, but do not be led astray when the system points in the wrong direction (either through failure or incorrect steerpoint selection). Turning at the identified turn point is obviously the maneuver of choice. However, if the turn point is not found, the turn to the next destination must be made based on timing or onboard navigation systems.

7.7.2. Visually Assisted Navigation (Map Reading). Map reading (also called "pilotage") is the determination of aircraft position by matching checkpoints on a map with their corresponding terrain or man-made features on the ground. Checkpoints should be features or groups of features which stand out from the background, are easily identifiable, and avoid known threats as much as possible. Avoid large towns and lines of communication (LOC). The basic procedure is to select a feature on the map and then find it on the ground, rather than work from the ground to the map. Steps for success:

- In flight, align the course line on the map with the nose of the aircraft so that features on the map appear in the same relative position as landmarks on the ground.
- Determine the approximate map position of the aircraft by cross-checking elapsed time on the clock versus the time marked on the map, as well as inertial navigation system (INS) mileage from programmed turn points.
- Cross-check your location with a significant checkpoint near this approximate position.
- It is important to work from the map to the ground since the map may not portray all features on the ground.
- If you are uncertain of your position, check every detail before confirming a checkpoint. Where a landmark is not available as a ground reference, fall back to DR/INS procedures and turn on time/INS.

7.7.3. Computer Assisted Navigation. The INS provides information to aid navigation and may be relied upon to assist navigation once it is proven reliable. Considerations when verifying navigation systems are:

7.7.3.1. Heading. To verify the precomputed heading, turn to the planned heading and then cross-check the destination bearing on the horizontal situation indicator (HSI). The HUD NAV steering bar/symbol is wind corrected and will be centered on the FPM when tracking directly for the destination.

7.7.3.2. Ground Speed (GS). Cross-check adjusted indicated airspeed/Mach against GS. At usual low-level density altitudes, GS will be slightly higher (approximately 5 to 10 percent) than the knots calibrated airspeed (KCAS) indicated. Also, verify GS by comparing INS miles-to-go versus time-to-go. For example, at 480 knots GS, when the distance measuring equipment (DME) indicates 24 NM to go to the destination, elapsed time should be 3 minutes less than the turn-point time. Adjust indicated airspeed only after confirming that the computer speed is reliable.

7.7.3.3. Position. The distance readout on the HSI (NAV) can be used to confirm the distance-to-go to a particular turn point or target and help to confirm present position.

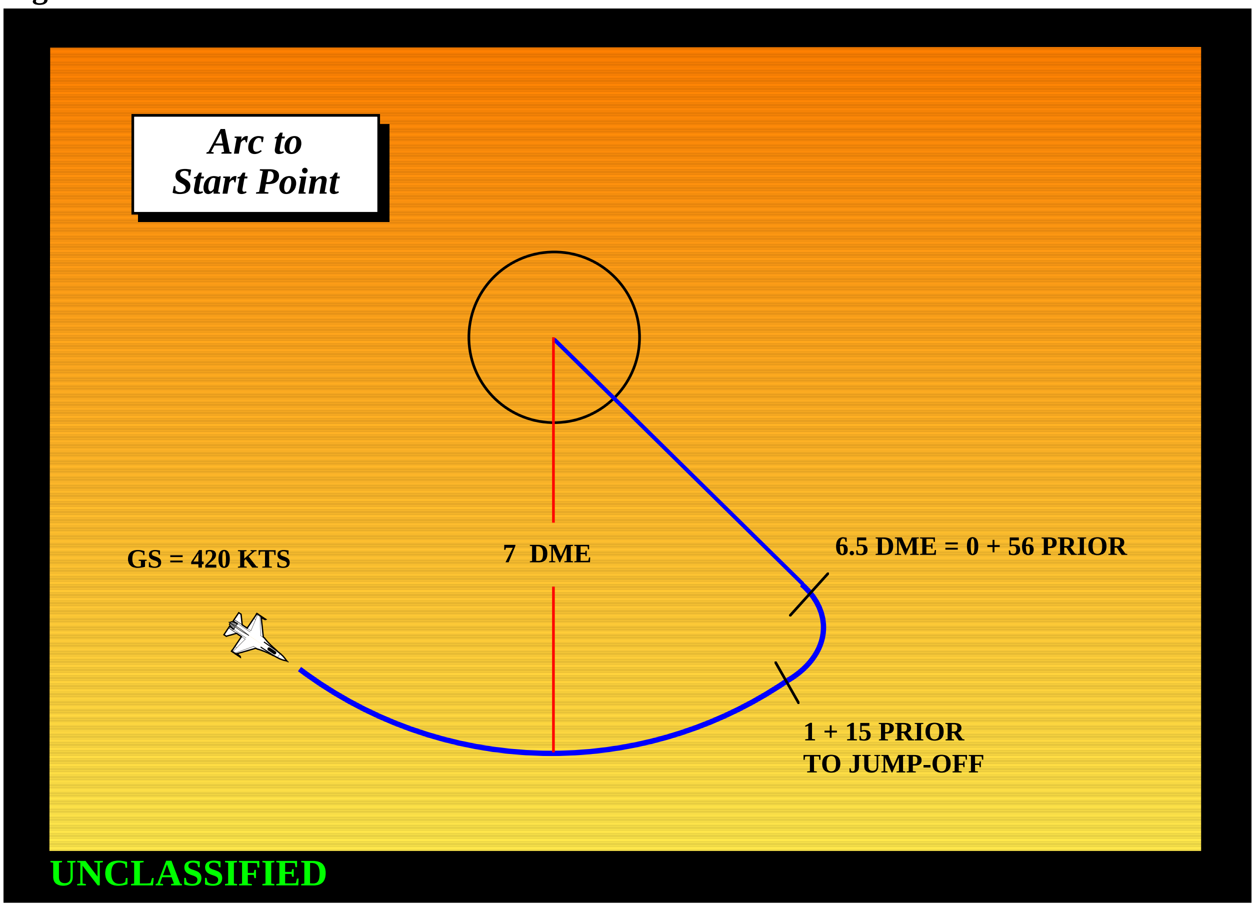
7.7.3.4. Time. Time-to-go information on the HUD should also correspond to the map and NAV DME versus GS. In addition, flight control computer (FCC) time-over-steerpoint (TOS) can be compared with computed real-times for very accurate timing adjustment.

7.7.4. Route Timing. The objective is to hit the target on time. Starting the route on time, at the planned airspeed and heading, will help you work towards achieving this objective. As a technique, allow some delay time between the planned takeoff and the start-route time. This extra time should compensate for late takeoffs, delays en route, or unforecast winds. Although flying faster than programmed, or cutting off part of the route can be used to make up time, fuel or threats may not allow it. Depending on the situation, it may be better to adjust TOT/TOS rather than burn excessive fuel to make up time. Be aware of the maximum route adjustment for the mission, both for time and fuel considerations.

7.7.4.1. Early Arrival. If you takeoff as planned, or early, delay arriving at the start-route point. Use the FCC to help pick a speed: the TOT/TOS clock is the key. If, even at maximum endurance, the TOS function still displays early arrival. Here are some alternatives:

- Start the route early and fly the first few legs slower than planned until on time. Maintain tactically sound airspeed.
- Arc around the start point until you compute it is time to turn towards it. Figure the time to fly direct from present DME to the point, add 15 seconds for a 60-degree bank turn of greater than 90 degrees and turn to the start point that much before planned jump-off time (**Figure 7.1.**, Arc to Start Point).

Figure 7.1. Arc to Start Point.



- Hold in a Race Track pattern, either en route or at the start-route point. ATC restrictions may require that you fly the pattern in the route structure, so know where you should and should not hold.

- Method 1: A viable variation of the TOT/TOS clock technique is to start the turn inbound, using a steep angle of bank (approximately 60 degrees), when the clock shows a 30-second early arrival. In order for this method to work, holding airspeed must equal route airspeed, and you must plan to be 180 degrees from the inbound course when 30 seconds early occurs. This method works well when holding in a threat area.
- Method 2: Use GS required on the TOS page. Turn in and accelerate with 3 to 4 Gs when the required GS is 50 knots below desired route speed. This method also requires you to plan to start 180 degrees from the inbound course, and is best used when holding more than 15 NM from the selected steerpoint. The primary advantage to this method is that holding is accomplished at lower power settings (saves fuel).

7.7.4.2. Time Adjustments. If crossing the start point at the hack time, fly the programmed GS. There are rules of thumb for adjusting speed to get back on time. For example, increase or decrease GS, configuration permitting, by 1/6 (for 480, change 80 knots) and hold the correction 1 minute for every 10 seconds you are off time. Normally, F-16 pilots take a more “macro” view and try to get on time by the next steerpoint, changing speeds until the FCC computed arrival time matches the planned time. If the required speed change is too great, try for on-time 2 or 3 points further down track. You can also gain or lose time by turning early or overshooting turn points.

7.7.5. TOS Clock. The FCC will project the elapsed time to a selected event and display it in the HUD. In the NAV mode, the event is TOS overflight, in continuously computed release point (CCRP) it is time-to-release, and in low-angle drague delivery (LADD) it is time to pull-up followed by time-to-release after passing the pull-up point. The FCC, once given TOS times, can by used to display a real-world time estimate to the next point. Mode selecting the TOT clock will then result in an airspeed caret being displayed in the HUD indicating the speed necessary to arrive at the selected point on time, effectively solving timing problems discussed in **paragraph 7.7.4.2**

7.7.6. Flying the Visual Low-Level Route. Cross your start point at the briefed altitude, on time, on airspeed. Hack the clock if necessary.

7.7.6.1. Determine whether or not you have an initial timing error or any INS drift with reference to your HUD steerpoint diamond.

7.7.6.2. Establish low-altitude referring to the cockpit altimeter, radar altimeter, and outside references. Emphasis at the start route point should be on the transition to low altitude. Tasks such as formation position, reading the map, hacking the TOS clock, and checking six should be done prior to low-altitude transition, or after you are established at low altitude wings-level flight. ***NOTE:*** Minimize heads-down time at the start route point. This is a critical time during the flight and attention to the velocity vector and altitude awareness cannot be over emphasized.

7.7.6.3. Adjust airspeed/GS to remain on time. Cross-check clock time at each turn point to confirm overall timing.

7.7.6.4. Remain on course by frequently cross-checking time/map/ground at predetermined points. To update systems, fly over or near the turn point. If an update is not required, flying directly over a point is not necessary. Remember, turn points are references to get to the initial point (IP) and target on time. If you do not visually acquire the turn point, turn when the INS indicates arrival or on-time.

7.7.6.5. Avoid these common tendencies:

- Power creep. Set, leave, and cross-check the exact throttle setting desired. Find a fuel flow that holds computed GS and return to this value after any throttle transient.
- Altitude variations. Strive to maintain the prebriefed AGL altitude for that portion of the mission. Reduce tasking to maintain that altitude. If tasking must override altitude awareness, climb to cope. Cross-check altitude at known steerpoints then return to "eyes out."
- Insidious heading changes. Cross-check heading to preclude course deviations resulting from poor heading control. Check aircraft rudder trim to center the "ball."

7.7.7. Flying the Radar Low-Level Route. Although radar navigation is the same as visual navigation in most respects, there are certain differences that require emphasis. Remember that the radar can improve system navigation accuracy.

7.7.7.1. Radar MSA. These altitudes should be indicated on the map. Cross the start point on altitude, with the same considerations as in visual navigation. The autopilot can be useful in maintaining above radar MSA while freeing your hands for other tasks. ALTITUDES MUST BE MONITORED. To verify DR calculations of position, when using the radar, use the TIMS checklist as shown at **Table 7.1.**, TIMS Checklist.

Table 7.1. TIMS Checklist.

T = Time	Check the time and find your approximate timed position on the map.
I = INS	Check your timed position with the heading and distance to the next turn point.
M = Map	Locate your approximate position on the map and determine the prediction of the point of interest.
S = Scope	Check the radarscope to verify your prediction, thus your position. If nothing can be positively identified, return to the clock and start the procedure over.
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7.7.7.2. Execution. Fly the route as a composite radar and visual mission. Visual sightings of radar returns will reinforce your faith in your radar prediction skill. Initiate turns over the route turn points.

7.8. Low-Altitude Maneuvering. There are many challenges during low-altitude operations requiring special emphasis due to increased risk for collision with the ground. Descents into the low-altitude structure and ridge crossings are two examples. Although these are discussed fundamentally, these principles apply when performing additional tasks such as high-to-low intercepts, pop-up bombing attacks, or threat avoidance during ingress and egress.

7.8.1. 50-Percent Rule. For high-low transitions, the 50-Percent rule is used to determine maximum safe flight path angle for a 90-degree turning roll-in (**Figure 7.2.**, 50-Percent Rule). The dive angle is equal to 50 percent of the pre-roll-in altitude AGL in hundreds of feet. For example, if your current altitude AGL is 4,000 feet, you can safely accomplish a 90-degree roll-in to a maximum 20-degree dive. If you are 2,000 feet AGL, 10 degrees is the maximum. This rule is easily applied to repositioning on a target from a pop-up or when rolling in on a tactical target from a Wheel pattern. Obviously, because of the variability associated with roll-in techniques, this rule is not precise. However, the 50-Percent rule does prevent the gross incorrect estimates of safe dive angles based on false human perceptions of AGL altitude.

7.8.2. 10-Degree Rule. The 10-Degree rule applies to low-high-low maneuvering such as pop-ups and vertical jinks over flat terrain. Start altitude is irrelevant; it relies on the control of time and geometry to ensure ending altitude clearance. The 10-Degree rule allows a return to low altitude after a timed climb. Climb at a set angle, for a certain time, roll inverted and pull down to a dive angle 10 degrees less than the climb angle, roll out (dive angle increases 5 degrees during roll), hold the dive for the same number of seconds as in the climb, then recover. In **Figure 7.3.**, 10-Degree Rule, climb angle is 20 degrees, climb is held for 5 seconds, roll-out is started at 10 degrees of dive (the nose drops an additional 5 degrees), the dive is held for 5 seconds, and then the pull-out is accomplished. The 10-degree rule allows unlimited tactical use of the aircraft's vertical maneuvering envelope while ensuring safe terrain clearance. The descent is 5 degrees less than the climb, making it an altitude-gaining maneuver. However, there are several factors which define this maneuver's limits. First, the rate of pull-down must be equal to or faster than the rate of pull-up. Second, airspeed during the pull-up and pull-down should be similar. Time control is imperative. Simply add extra time to the climb portion of the maneuver in order to give more buffer.

7.8.3. Ridge Crossings. Crossing ridge lines is a dangerous move. The aircraft is highlighted to threats, so avoid ridge crossings if at all possible. Many situations force you to cross ridges. If possible, cross a ridge at its lowest point, or in a saddle. Sound planning, and practice of ridge crossing techniques, can be a great aid. Three techniques are commonly employed:

Figure 7.2. 50-Percent Rule.

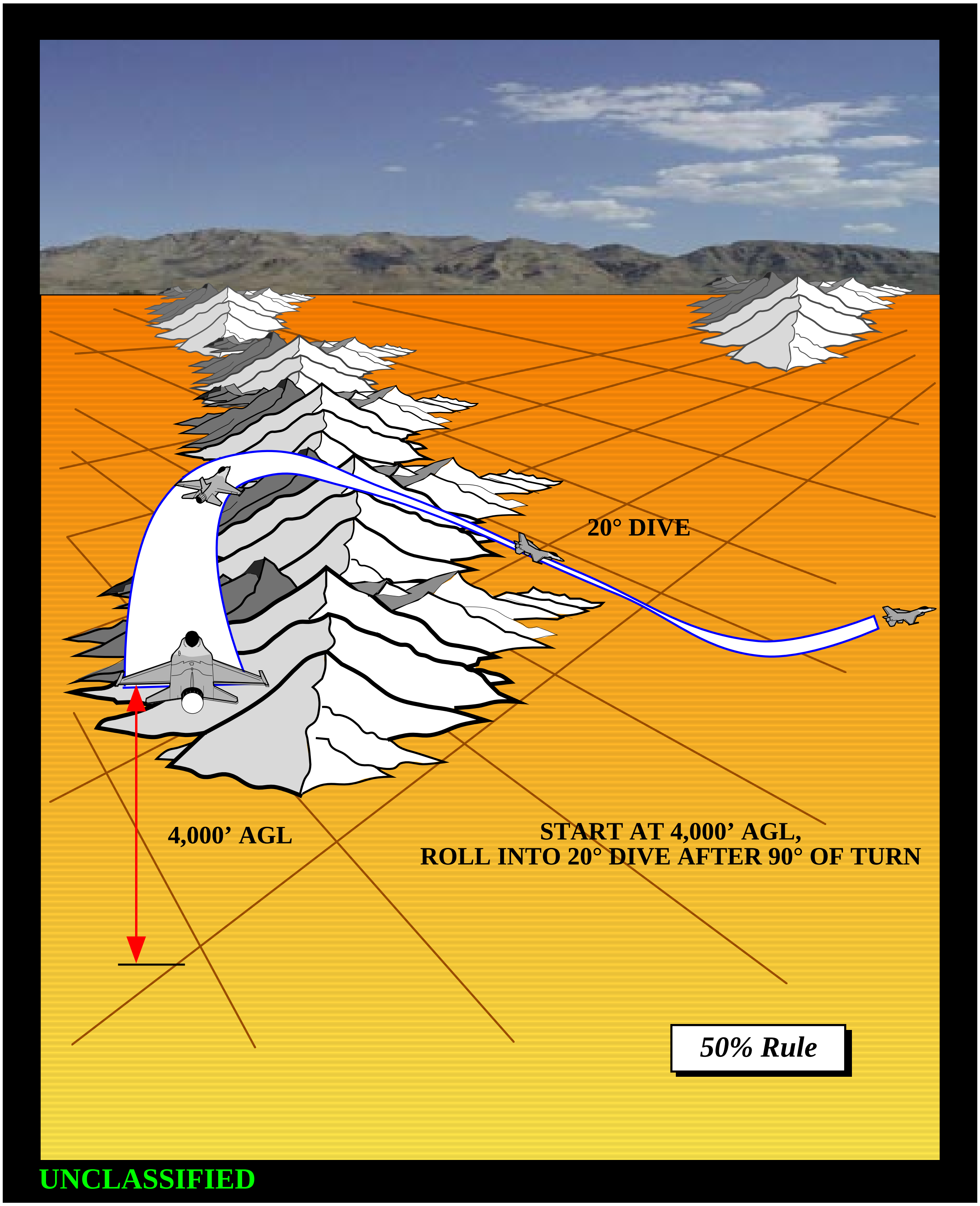
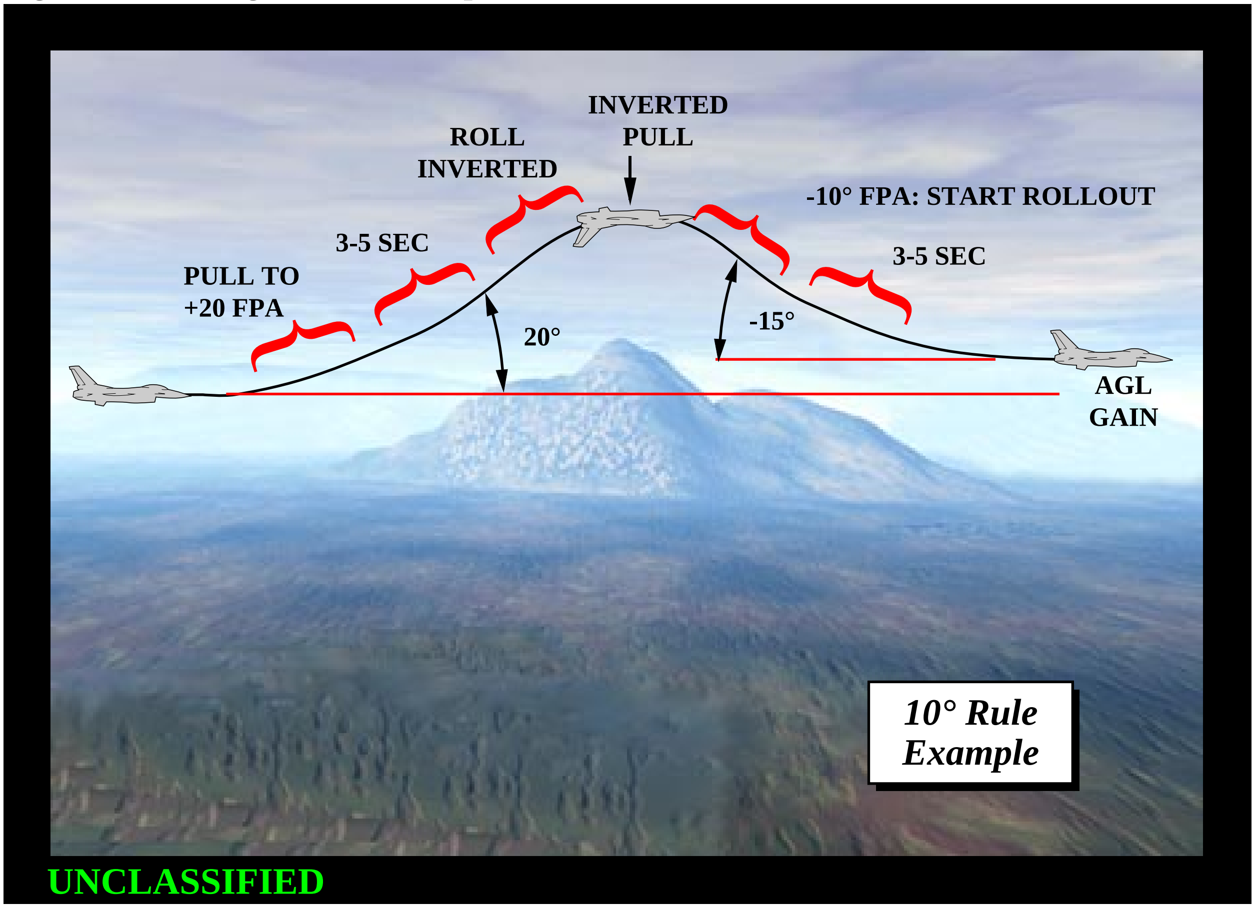
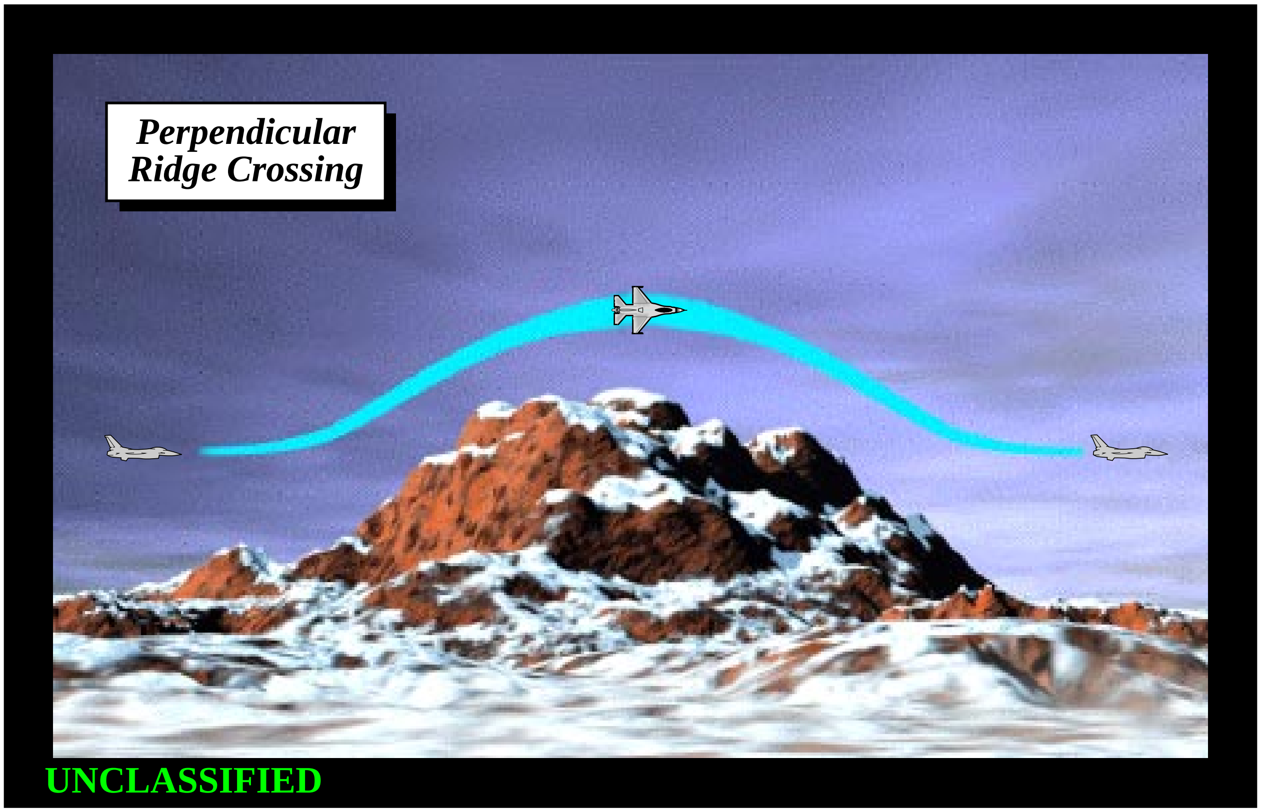


Figure 7.3. 10-Degree Rule Example.



7.8.3.1. Perpendicular. This crossing minimizes enemy radar or visual acquisition but should be done only when you know your six is clear. Use power as required to maintain tactical airspeed during the pull-up. Pull early to avoid a large overshoot crossing the ridge, and crest the ridge at your specified minimum low-level altitude. Go down the back side and either bunt or roll and pull. Totally inverted pull-downs are prohibited. At the crest, unload and roll to approximately 135 degrees, then slice down. At the desired nose-low position, roll out and resume low-level flight. Initial attempts at this technique should be limited to a 15-degree nose-low attitude. DO NOT bury the nose in the new valley. This maneuver may put you belly up to unexpected high terrain on the other side of the mountain, and the wing flash during the maneuver is highly visible to threats. The roll and pull technique is most effective when crossing large, steep, isolated ridge lines. A bunt or pushover is more appropriate over milder, rolling terrain. The pull-up for a bunt or pushover should be initiated early enough to avoid excessive ballooning over the ridge. The advantages of the bunt are straight-line navigation, no wing flash, and less disorientation (**Figure 7.4.**, Perpendicular Ridge Crossing).

Figure 7.4. Perpendicular Ridge Crossing.

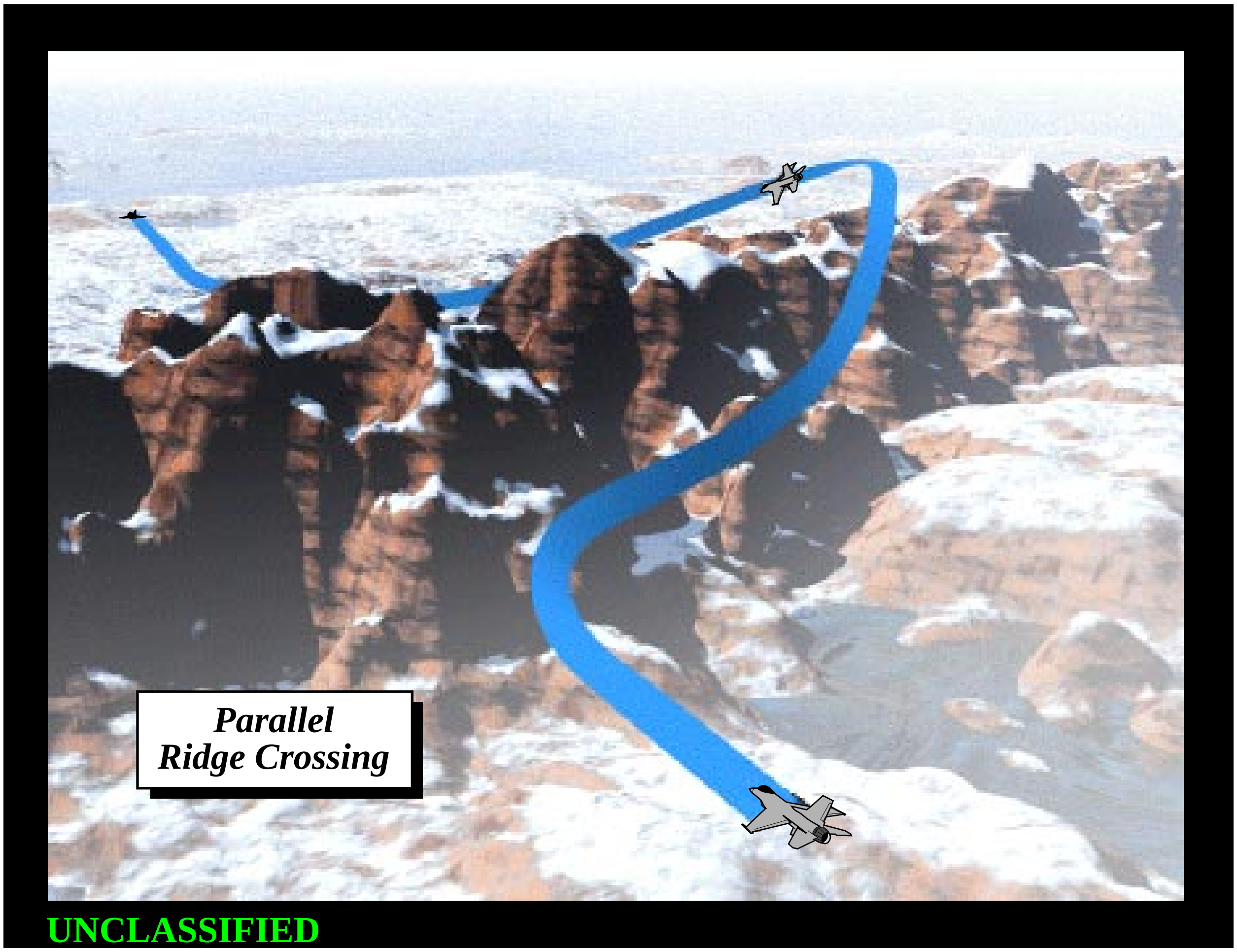


7.8.3.2. Parallel. Use this type of approach if your six is, or may be, threatened. It can deny the bandit a blue-sky background and provide a difficult guns environment. Turn to arrive at the pull-up point with approximately 45 degrees of crossing angle to the ridge. Pull up later than for a perpendicular crossing, and continue to turn in the climb to end parallel to the ridge crest just below the top. Roll and pull into the ridge; cross the crest at your specific minimum altitude. Continue a loaded roll to fly down the backside of the ridge, on a heading 90 to 135 degrees from the ridge line. Roll out and continue (**Figure 7.5.**, Parallel Ridge Crossing).

7.8.3.3. Saddle. The saddle type ridge crossing is similar to the parallel and can be used when threatened. Turn to parallel the ridge line below the crest until you can use a saddle, canyon, or the end of the ridge to cross to the other side. The exact maneuver is dictated by the terrain characteristics, but can be similar to a level turn (**Figure 7.6.**, Saddle Ridge Crossing).

7.9. Emergencies/Abnormal Operations at Low Altitude. Emergencies may happen at 500 feet and below, but you do not "handle" them there. Items such as aircraft malfunctions, bird strikes, disorientation (loss of awareness), lost sight (wingman) and weather deterioration are critical at low altitude and need something such as an "initial move" prior to even looking at the problem. To generalize the handling of unusual occurrences, a response has been developed that covers all problems at low altitude: climb to cope. Climb any time you are not coping with your situation. Then, after initiating a climb, maintain aircraft control, analyze your situation, and turn toward the appropriate landing field or continue your mission as appropriate.

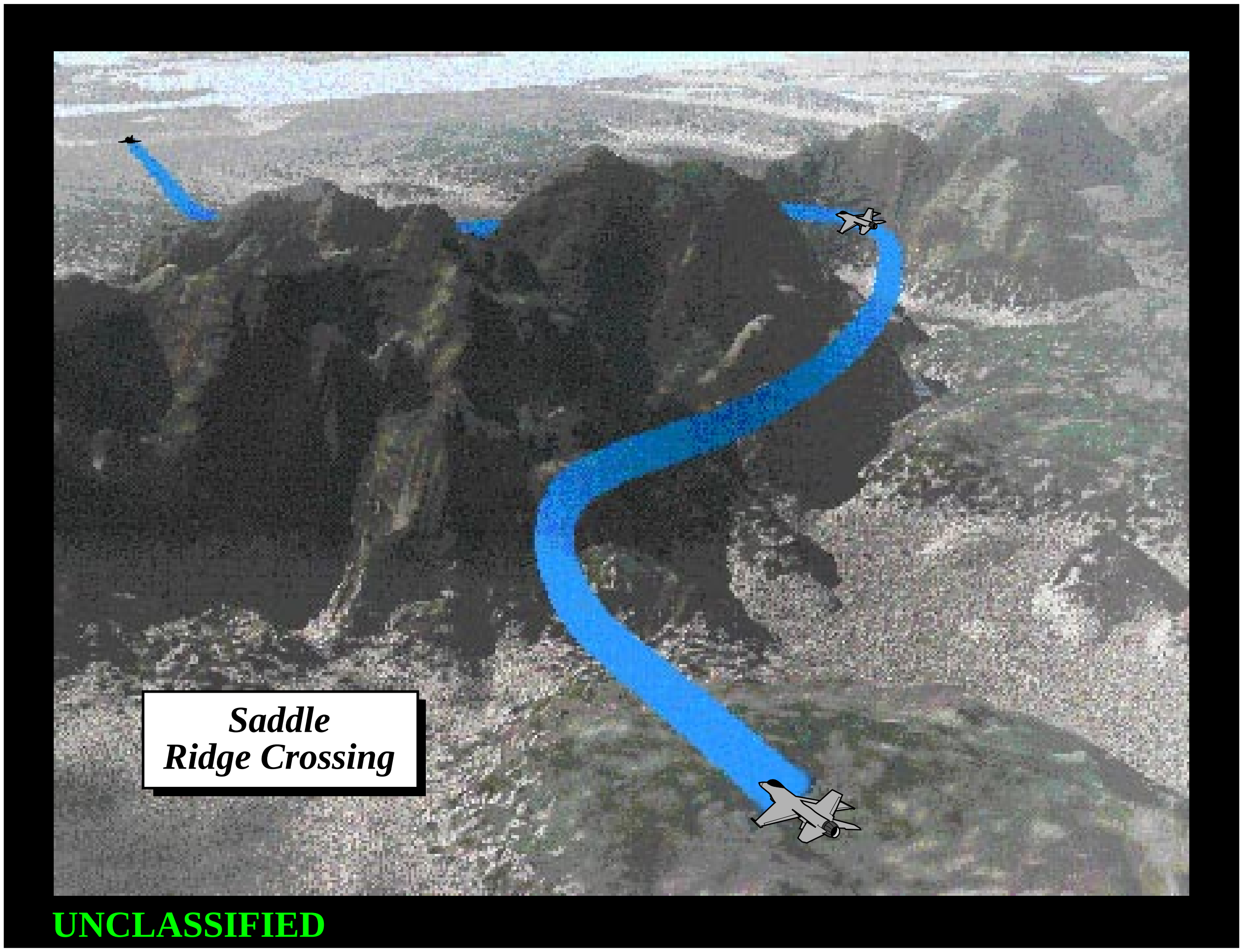
Figure 7.5. Parallel Ridge Crossing.



7.10. Route Abort Procedures. The best route abort plan is one executed well before the flight encounters instrument meteorological conditions (IMC). Constantly monitor down-track weather either visually or with snowplow on the radar. If possible, alter the route to maintain visual meteorological conditions (VMC). If unable, clear the wingmen to fighting wing and execute a 180-degree turn to maintain VMC, allowing the trailing element to follow. Another option is to execute a hook left/right and allow the previously trailing element to lead out. As a last resort, if IMC is encountered, lead should transmit "VIPER 1, ROUTE ABORT." At this time, flight members should slightly turn away from the element mate's last position while selecting AB and establishing a 30-degree nose-high attitude. Transition to flight instruments is critical. Deselect AB and level off at or above the RAA/MSA IAW the briefed game plan or VMC as appropriate. Trailing elements should avoid IMC by using the desired avoidance procedures, if able. Stay VMC-squawk EMERGENCY if required or still IMC. MCI 11-F16V3, *Pilot Operational Procedures —F16,* contains additional guidance. Large packages require a detailed flight briefing for the desired route abort procedure.

7.11. Low-Altitude Formations. Low-altitude formations and responsibilities are covered in detail in **Chapter 3.**

Figure 7.6. Saddle Ridge Crossing.



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CHAPTER 8

NIGHT OPERATIONS

8.1. Introduction. The information in this chapter, combined with a thorough knowledge of appropriate sections of MCI 11-F16V3, *Pilot Operational Procedures—F-16* and local procedures, will prepare pilots for safe and effective night flying.

8.2. Night Ground Operations. Special care should be taken during night ground operations. Allow extra time to complete the exterior preflight, since flashlight illumination is minimal. Ensure the canopy is clean. Check the exterior lights during preflight to ensure they are not missing or broken.

8.2.1. Operations Checks. The only lights available from battery power are the utility light and the cockpit spotlights (eyebrow lights). Remove the utility light from its retaining post prior to strap-in, as desired. Ensure you are able to monitor revolutions per minute (RPM) and fan turbine inlet temperature (FTIT) during start until the generator is on line and additional lighting is available; use your flashlight if necessary. After start and any other time the aircraft is stopped on the ground (maintenance quick check/arming/de-arming), the position lights should be bright and steady, and the anti-collision strobe should be set to OFF. This helps prevent possible ground crew disorientation and gives them better illumination with which to complete their operations. Check the operation of landing and taxi lights immediately after engine start.

8.2.2. Taxi. When ready to taxi, turn the strobe on, the position lights to flash, and the taxi light on. Taxi at night IAW MCI 11-F16V3, *Pilot Operational Procedures—F-16* and local procedures. Because the nosewheel door blocks some illumination of the taxi light (N/A for Block 40/50), visibility to the left of the nose is limited. The landing light may be used during left turns.

8.3. Night Takeoff. The night takeoff is essentially an instrument takeoff. Either the taxi light or landing light may be used. A recommended technique is to set the head-up display (HUD) declutter switch to attitude (ATT)/flight path marker (FPM) for night and/or instrument takeoffs; otherwise, you will lose the HUD pitch/attitude ladder when the gear is retracted. Use the HUD/attitude direction indicator (ADI) in combination with available visual references (e.g., runway lights) to maintain runway alignment. Establish the climb attitude in the HUD and cross-check with primary control and performance instruments. Special consideration should be given to a potential visual illusion of increasing pitch attitude due to landing gear retraction caused by the position of the landing/taxi light.

8.4. Night Formation. Night formations are greatly dependent on environmental conditions. On clear nights with high moon illumination, formations can be used which are very much like day formations. As conditions degrade, formations must be modified to accommodate reduced visibility and depth perception.

8.4.1. Night Weather Formation. Night weather formation flying requires modification to daytime weather procedures. Anticipate weather entry and accomplish either a rejoin or split up the formation while visual meteorological condition (VMC) exists. The preferred formation is non-standard radar trail with 1 to 2 NM between element mates. If join-up is desired, ensure all flight members turn their strobe light off upon weather entry to avoid possible spatial disorientation. Use smooth corrections and avoid rapid or erratic control inputs. Lost wingman procedures should be used if you lose visual references (Fingertip/Route) or positional awareness (radar trail).

8.4.2. Fingertip/Route Formation. Flown in the same position as day formation. However, many visual cues may be absent or more difficult to observe. (See **Figure 8.1.**, Night Fingertip.)

Figure 8.1. Night Fingertip.

8.4.2.1. Day/Night Similarities. The night position is the same as the daylight close formation position. Start by aligning the upper wingtip position light with the top (canopy) formation light. This places you farther back than normal, so once you settle down in this position, move forward until the top formation light, bottom formation light, and position light on the engine inlet form an equilateral triangle.

8.4.2.2. Vertical Alignment. Vertical alignment is within acceptable bounds when you make the inlet position light approximately equidistant between the top and bottom formation light.

8.4.2.3. Vertical Spacing. When fore, aft, and vertical spacing are correct, your head is approximately abeam the floodlight which illuminates the lead aircraft's tail or abeam the lead aircraft's tail light (just above the nozzle). Avoid fixation on any one light or reference point.

8.4.3. Trail Formations. Trail formations form the fundamental basis for in-flight deconfliction as well as provide for mutual support. Additionally, deconfliction is optimized with altitude separation between flight members. The primary reference for station keeping (spacing and position) is the radar, backed up by the air-to-air (A/A) tactical air navigation (TACAN). For admin/en route trail, normal spacing is 2 to 5 NM between trailing flight members. For ingress and egress trail, spacing will normally be a function of the A/A game plan and/or target area deconfliction considerations (reference Advanced Employment Manual 3-1, Volume 5 for detailed tactical trail considerations). A technique for monitoring position is to continue normal radar search while maintaining awareness of lead's position near the bottom of the scope. A rule-of-thumb is to position the radar hit of the preceding aircraft on the top of the 10-/20-/30-degree azimuth tick on a 40-NM scope. In all cases, lead should thoroughly brief desired range and aspect for the wingman's position to ensure formation integrity. The disadvantages of trail formation are the same as day: a loss of visual lookout and visual mutual support.

8.4.4. Lead Considerations.

8.4.4.1. Lighting. As lead, configure exterior lights according to the wingman's desires as much as possible. The anti-collision strobe should be flashing until the wingman has completed the rejoin and then placed in the OFF position. Initially, try a setting of dim/steady for the fuselage and position lights and mid-range for the formation lights. In dim/steady/strobe off, all exterior light toggle switches will be aft/inboard.

8.4.4.2. Maneuvering. Make all maneuvers smooth and coordinated to minimize the possibility of inducing spatial disorientation. Make frequent cross-checks of the wingman's position. If formation break-up is required, do so in straight and level, unaccelerated flight and only after determining that the wingman has operational navigational equipment, understands his position, heading, altitude, airspeed, and clearance. Monitor the wingman closely as the separation proceeds.

8.4.5. Wingman Considerations.

8.4.5.1. Formation Flying. Flying the wing position at night presents some of the same difficulties as flying formation in the weather. As such, spatial disorientation will be of special interest. To the greatest extent possible, keep abreast of the situation and plan ahead to predict maneuvers. The primary attitude indicator will be the lead aircraft. Whenever possible, cross-check the HUD and control/performance instruments to verify attitude.

8.4.5.2. Night Specifics. The lack of visual cues, coupled with the lack of depth perception, contribute to night formation problems. In close formation, use the alignment of the formation lights to maintain fore, aft, and vertical position and learn to gauge separation from the size and spacing of these lights. Stay alert for any clearances transmitted or any other indications of imminent changes in flight position, heading, altitude, and airspeed. Be prepared to accept the lead of the flight at any time if required by an emergency or other flight break-up situation. Know the planned instrument recovery and minimums before takeoff. If operations inside the cockpit are required (e.g., radio frequency changes), make slow, deliberate changes and glance inside the cockpit briefly to check the results. Do not take your eyes off the lead aircraft for any extended period of time.

CHAPTER 8-4

8.5. Night/Weather Intercepts. Night or weather intercepts present a unique challenge since, in addition to flying good instruments, you must include the radar in your instrument cross-check. Primary consideration must be given to maintaining aircraft control by instruments, and very little time (if any) should be devoted to outside visual references or attempting to get a tally. This is contrary to what was taught during day VMC intercept missions. Attempting to attack another aircraft at night or in the weather is demanding and can be spatially disorienting; especially in the F-16.

8.5.1. Cockpit Setup and the Bubble Canopy. It is important to have the cockpit and switches set up as early as possible. This helps you stay ahead of the jet. Set up cockpit lighting as low as comfortable. Use caution to ensure you do not lower contrast too low and cut off target histories. The pilot must compensate for the F-16's vertigo-inducing effects with a good composite instrument cross-check.

8.5.2. Ground-Controlled Intercept. At night or in weather, ground-controlled intercept (GCI) control can be of great value; be aware of controller and radar limitations. Pay attention to the controller's instructions. Remember, radar situational awareness (SA) provides an accurate way to update information.

8.5.3. Altitude. Altitude separation from the target should be reduced during night/ instrument meteorological conditions (IMC) to avoid large pitch changes at the merge. Usually 2,000 to 4,000 feet above or below the target is sufficient. Continually monitor your altitude during all phases of the intercept. This helps to avoid deviations which could violate the target's altitude block or cause impact with the ground.

8.5.4. Auto-Pilot. This may be used, but constantly monitor its performance. Remember, it will not maintain altitude at high angle of attack (AOA)/slow airspeed. No warning occurs if it is not holding your altitude.

8.5.5. Turns. In night/weather conditions, make all turns at the lowest G that's appropriate. When making turns, concentrate on aircraft control and do not allow yourself to be distracted with radar, GCI, or other inputs. One technique is never use more than 60 degrees of bank without full attention on instrument flying. At night, increase lateral displacement so that the conversion turn requires less G. Throughout the intercept, keep the aircraft stabilized as much as possible in altitude, airspeed, and bank angle so that you do not become preoccupied with large corrections back to the desired parameters. This will allow you more time to analyze the radar and basic intercept geometry.

8.5.6. Instrument Cross-Check. It is tempting to rely on occasional outside visual references and other unreliable sensory cues rather than on instruments to maintain aircraft attitude. It is critical to develop a composite cross-check to maintain situational/spatial awareness. Large and often insidious changes in aircraft attitude, altitude, and airspeed can go undetected, unless there is frequent reference to instruments.

8.5.7. Sitting Height. Consider a lower sitting position at night. A high sitting position requires you to look well down into the cockpit to check instruments. The head movements made between HUD references and cockpit instruments can contribute to spatial disorientation. The primary means to fly night/IMC intercept must be via instruments.

8.5.8. Heads-Up Display. Since some basic attitude information and almost all weapons information is displayed on the HUD, it may be tempting to allow too much time to the HUD cross-check at the expense of a basic instrument scan. This, in turn, may tempt you into noticing/searching for outside visual cues. While use of the HUD may be helpful, do not let it become distracting.

8.5.9. Afterburner. If selected, the rapid acceleration can cause a climbing illusion. Selection of the afterburner in weather will sometimes cause a startling bright flash. The use of afterburner at night will also highlight your position.

8.5.10. Lost Contact. A lost contact during the intercept should not be a cause for hasty or improper action. The first priority (as always) is to maintain aircraft control and ensure proper altitude separation. Do not be reluctant to skip it, knock it off, or blow through if SA or other circumstances dictate. If you elect to continue the intercept, reestablish GCI control by calling for “BOGEY DOPE” and request close control, until contact is regained. If outside 10 NM with no contact, consider aborting. Inside 10 NM, use slewable air combat maneuvering (ACM) and bracket the target's last known altitude. If in the conversion turn when contact is lost, ease off the turn (or roll out momentarily) to ensure you will end up behind the target and remain in your block. Then turn to the last known target heading and begin searching for the target with the radar (if you can confirm the target is not maneuvering).

WARNING: DO NOT drive (for long) on any heading other than the target's and DO NOT use visual references in an attempt to save the intercept. This invariably results in large altitude/attitude deviations, seldom saves the intercept, and often leads to spatial disorientation.

8.5.11. Visual Reference Considerations. The tendency to use the HUD as you would in a visual attack can be unsafe during night or IMC. Some reasons for this are:

- You do not know if you are looking at the real target or just some “other” light.
- You cannot judge range and closure rate.
- You may be visually maneuvering your jet into an unusual attitude. (Furthermore, a real target will not have his beacon on at night!) You must perform frequent instrument cross-checks during night/IMC intercepts. The emphasis should be on instruments until approaching weapons launch range.

8.6. Night Surface Attack. Preparation for flying night missions, especially night surface attack, demands thorough and accurate planning. All of the normal items required for daytime operations need to be accomplished and double-checked for accuracy. Errors which you might easily catch in flight during the day can mislead you at night and go undetected for too long. Be sure the inertial navigation system (INS) and weapons data are good. In addition to the usual items, review the following subjects:

- Aircraft interior lighting.
- Aircraft exterior lighting.
- Emergency lighting (generator failure).
- Night visual signals (radio out).
- Alternate airfield night lighting.

CHAPTER 8-6

8.6.1. En Route Procedures. Route of flight and en route procedures will vary IAW local procedures. Your route to the range may include a night air refueling, a night low-level, or simply be a medium-altitude direct route. Procedures at night are similar to daytime with the following exceptions:

- Visual ordnance checks are not made at night.
- Formation position changes are directed over the radio.
- Low-level routes are flown at higher minimum altitudes (see MCI 11-F16V3, *Pilot Operational Procedures—F-16*).

8.6.2. Range Layouts. The specific layout of night ranges vary with each local range. Three of the more common layouts are shown in **Figure 8.2.**, Typical Night Ground Illumination—1; **Figure 8.3.**, Typical Night Ground Illumination—2; and **Figure 8.4.**, Typical Night Ground Illumination—3. Refer to the local supplement to AFI 13-212V2, *Weapons Range Management*, to determine range lighting type. The individual marking devices could be either flare pots, lanterns, or electric lights. Most ranges use flare pots on the "bull" since it is likely to take numerous hits.

8.6.2.1. Target Illumination. No matter which type of ground illumination is used, the intensity of the markers is normally quite dim. In addition, some of the lights may be out for various reasons. These factors can combine to make it difficult to distinguish the target from other lights in the area. Each range has its own peculiar set of false lights and illusions. Positive identification of the target is absolutely essential, so be sure you know exactly what to look for.

8.6.2.2. Lighting Compensation. On a real "dark night" you may have to maintain your position by reference to target area lighting only. Realize that the array of lights around the target will have a different appearance depending on the angle at which you view them. Other lights which may help maintain orientation are the obstruction lights on the main and flank towers. These lights should be distinguishable by their different color (red).

8.6.2.3. Flares. If flare support is available from another aircraft, your job of seeing the range/target area can be vastly simplified. However, you may have to find the range on your own prior to the flareship dropping any flares.

8.6.3. Range Entry Considerations. Getting clearance on the range is similar to daytime operations, with certain additional requirements:

8.6.3.1. RCO Operations. Clearance must be received from the range control officer (RCO) who must ensure deconfliction between the fighters and any flare support aircraft. This is normally done by altitude separation. Target identification is often difficult and the RCO may be needed to help direct the flight to the range.

8.6.3.2. Pattern Limits. A maximum of three aircraft will be allowed in the pattern (one may be a flareship).

Figure 8.2. Typical Night Ground Illumination—1.

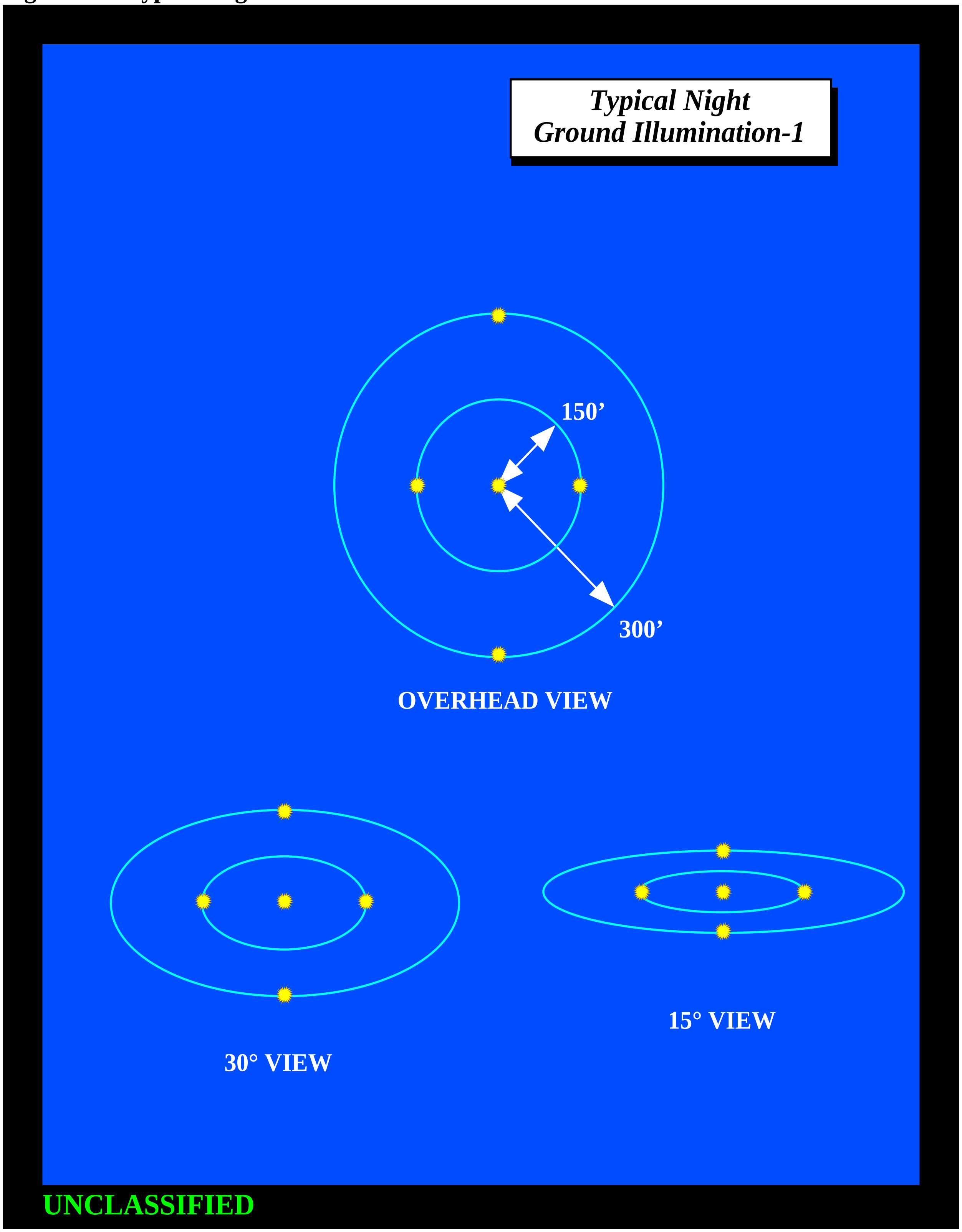


Figure 8.3. Typical Night Ground Illumination—2.

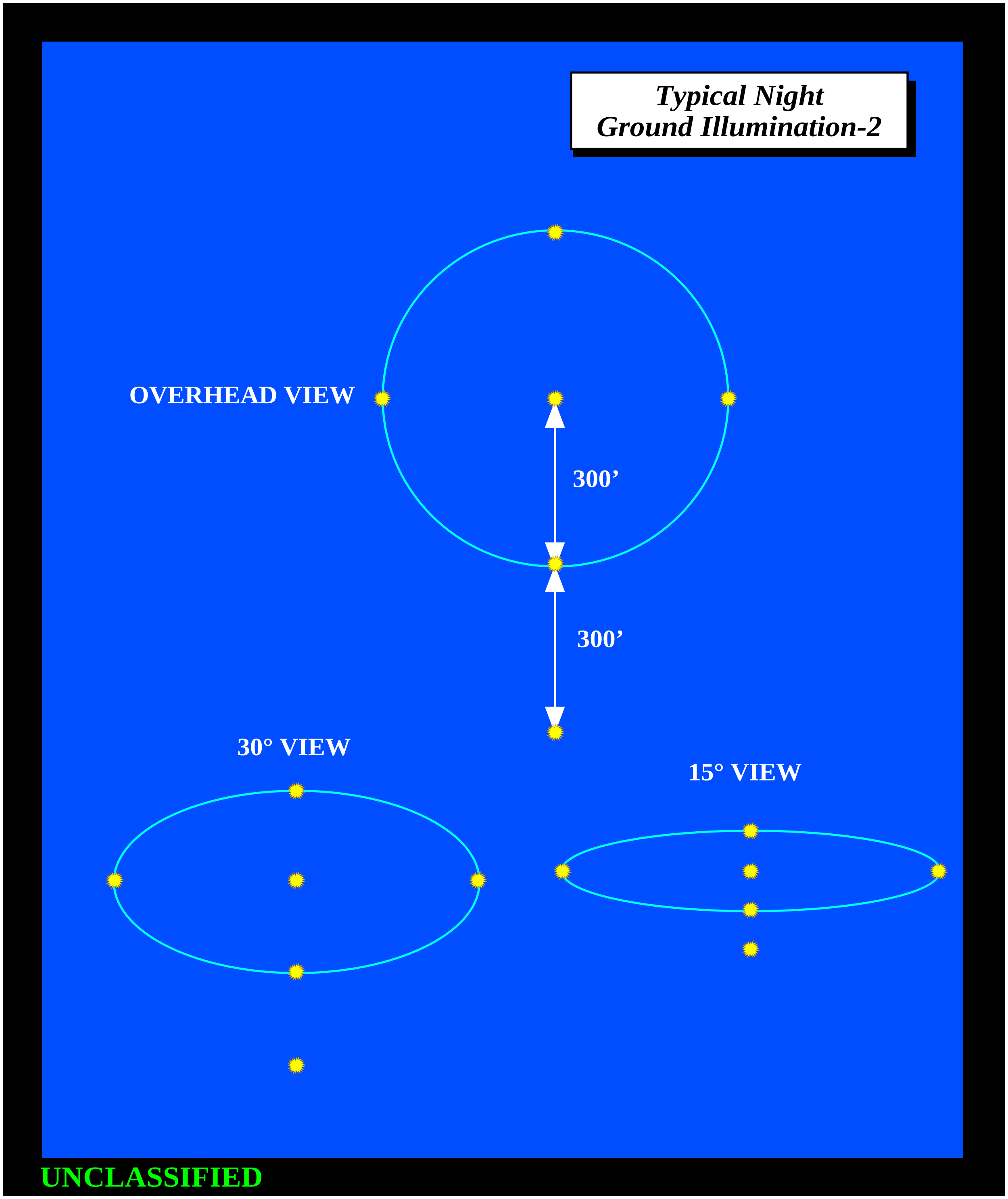
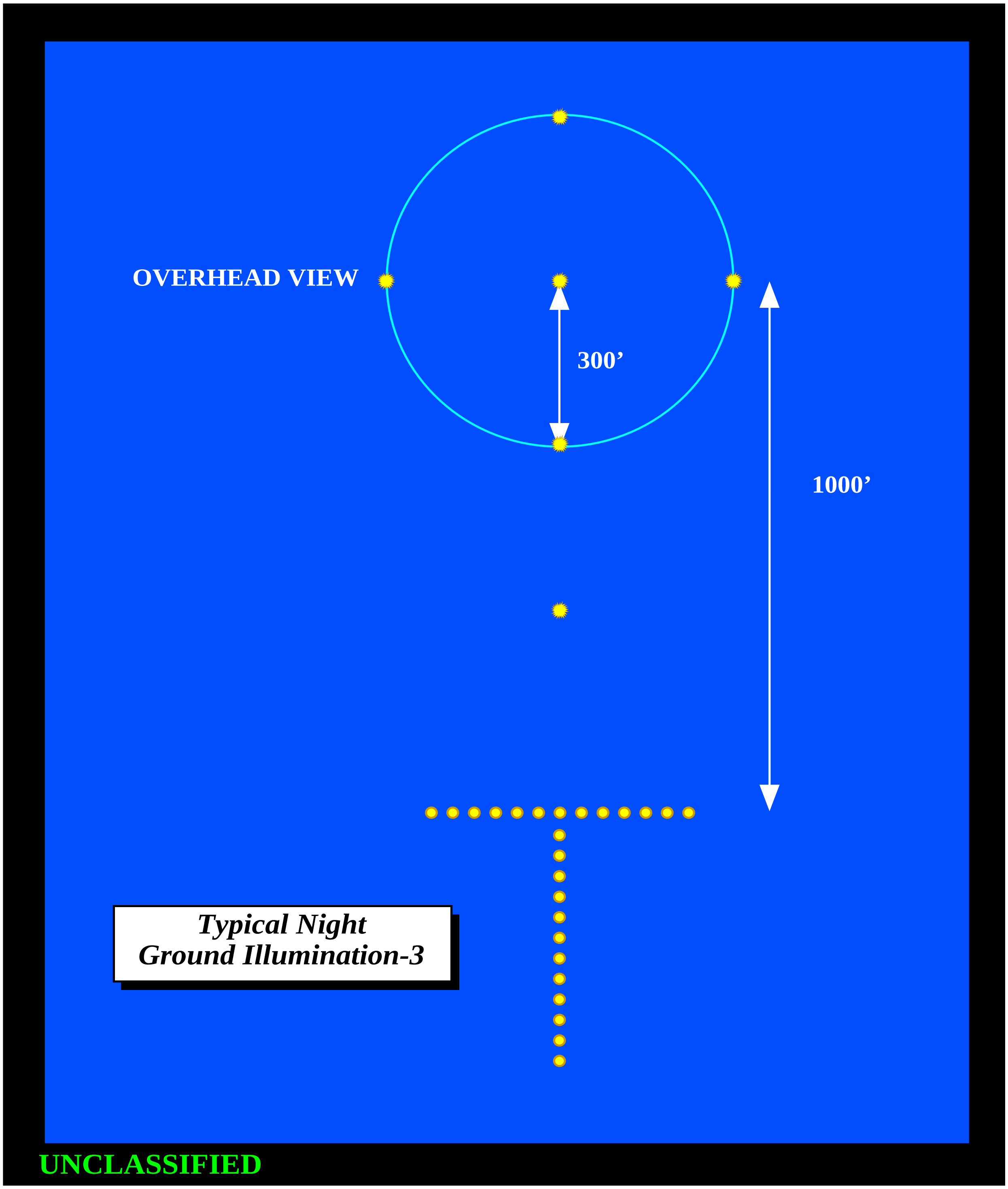


Figure 8.4. Typical Night Ground Illumination—3.



8.6.3.3. Radar Entry and Events. It is common to enter the night range pattern from a non-conventional delivery pass. Night non-conventional procedures are similar to day with the following exceptions and special considerations:

8.6.3.3.1. Altitudes. Minimum run-in altitude should be the same as night low-level navigation. Minimum downwind altitude is 1,500 feet AGL (MCI 11-F16V3, *Pilot Operational Procedures—F-16*).

8.6.3.3.2. Communications. Call "FINAL, (EVENT), (ALTITUDE)" at the initial point (IP).

8.6.3.3.3. Event Illumination. Non-conventional targets do not have to be illuminated at night.

8.6.3.4. Flight Discipline. Strict discipline with respect to maintaining proper altitude, heading, and airspeed is critical. There are many tasks to be performed in the cockpit in order to make a radar delivery, but the most vital ones are maintaining aircraft control and not hitting the ground. You simply cannot afford to spend any extended period of time doing things like reading a map/checklist, or adjusting the radar gains, without cross-checking your instruments. Good preflight planning, to include the pacing of your tasks, will go a long way toward minimizing misprioritization.

8.6.3.5. Autopilot Use. Just as in daytime, the autopilot can be useful in maintaining altitude while doing other tasks. However, THE AUTOPILOT MUST BE MONITORED. Always check it's function after you turn it on and ensure that you are in the altitude hold function of the autopilot. There are several autopilot failure modes that do not give the pilot warning.

8.6.4. Foul Avoidance. The RCO's judgment of foul parameters is impaired by darkness. The RCO may foul you prematurely, or even worse, fail to foul you when you really deserve one. Fly your aircraft like a professional and neither one will happen. ***NOTE:*** Night controlled range minimum recovery altitudes are shown in **Table 8.1.**, Minimum Recovery Altitude (Night Controlled Range).

Table 8.1. Minimum Recovery Altitude (Night Controlled Range).

Event	Minimum Recovery Altitude
20˚ to 35˚ Dive	2,000 feet AGL
35˚ Dive	4,500 feet AGL
15˚ to 20˚ Low Angle Low Drag	1,000 feet AGL
NOTE: Planned deliveries exceeding a 45˚ dive angle will not be flown.	
UNCLASSIFIED	

8.6.5. Night Box Pattern. Essentially, the night attack patterns on a controlled range are the same as those flown in the daytime. Because of visibility restrictions, a slightly larger pattern is recommended.

8.6.5.1. Spacer Pass. The spacer pass may be flown from a standard formation pass over the target, or it might be from a simple pitch up to downwind from a non-conventional pass. No matter how you split up, it is critical that you take the pre-briefed spacing and pitch up in a manner that does not immediately induce vertigo. Use about 45 to 60 degrees of bank and 2 to 3 G's in the break. Have the horizontal situation indicator (HSI) set up with a reference on the run-in heading so that you can quickly assess your heading with respect to the pattern headings. The night pattern should be flown much more "mechanically" than in the day.

8.6.5.2. Crosswind. When turning crosswind any time in the night attack pattern, there is a stronger chance you will turn inside of the preceding aircraft. Rolling out wings-level momentarily (3 to 5 seconds), and looking outside as well as inside your turn, will help to avoid passing or colliding with other flight members. In addition, this momentary roll out will aid in keeping the pattern from becoming uncomfortably tight.

8.6.5.3. Downwind. Daytime considerations apply. Avoid the "moth effect" tendency to allow the pattern to gradually become tighter and tighter around the small, well-lit target area. All switch changes will be accomplished wings-level on downwind. Turn position lights to bright-flash, strobe light on, and formation lights full bright (IAW AF and 55 series directives).

8.6.5.4. Base. Determine the required base leg distance from the target for the particular event being flown. Exact base leg position is harder to fly at night since you do not have the normal daytime ground references. Here are some commonly used techniques:

8.6.5.4.1. Time your downwind leg from a point abeam the target. Time approximately 6 to 8 seconds from the point abeam the target. Start a 2 to 3 G turn to base at the end of this time.

8.6.5.4.2. Use the same angular relationship of the target position over the canopy rail as you do in the daytime. ***CAUTION:*** Be sure you are wings-level. A shallow bank into the target will cause you to angle-in.

8.6.5.4.3. Reference to the length of the lighted "T," or other run-in markers, (if available) will help get your base correct.

8.6.5.5. Roll In. Night roll in is similar to daytime, except that you need to cross-check attitude instruments to avoid getting disoriented. There is a tendency to undershoot final on the first few patterns. Reference the lighting on other objects, such as the range/flank tower to give the idea of when to begin the roll in. All night patterns will be basic versus tactical deliveries.

8.6.5.6. Final. At night, place additional emphasis on the parameters of each pass (dive angle, altitude, airspeed).

8.6.5.7. Recovery. Recover so as not to descend below minimum recovery altitudes, regardless of whether ordnance is released or not. Strict attention to cockpit instruments is of paramount importance. Initiate recovery using a wings-level 5 G pull up and do not initiate turns until the aircraft nose is definitely above the horizon. DO NOT attempt to observe your own bomb impact at night. The lack of visual attitude recognition can lead to spatial disorientation.

8.6.6. Night Range Radio Procedures. The need for strict radio discipline increases dramatically in the night range pattern. The following radio calls and pattern locations are mandatory:

- When directly abeam the bomb circle, transmit: "TWO'S, DOWNWIND"

- Starting the turn onto base, transmit: “TWO'S, BASE”
- As you start the turn onto final, transmit: “TWO'S, IN” (Add “FLARE SHIP IN SIGHT,” if required).
- During recovery, transmit: “TWO'S, OFF WET” OR “TWO'S, OFF DRY”

8.6.6.1. Crucial Radio Calls. The additional radio calls in the night pattern increase the chances of blocking out the two most important calls which are the call “in” by the aircraft turning final and the clearance call by the RCO. If necessary, delay other calls when you sense these two calls are about to take place.

8.6.6.2. Hung Bomb Call. A “NO SPOT” from the RCO should be interpreted as a hung bomb at night. Continue range operations (if range restrictions allow) and recover using hung bomb procedures IAW local directives.

8.6.7. Night Range Departure Procedures. With a few minor exceptions, the night range departure is similar to the day procedure. Ordnance checks are not required at night. If you recover as a formation the following guidelines apply:

- Wingmen will acknowledge the number of aircraft in sight.
- Avoid dropping low during the rejoin.
- Expect lead to roll out.
- Lead will transmit exact heading and altitude.
- Wingmen will join in order.

8.6.8. Night Computed Bombing. Computer assisted bombing in the F-16 makes it possible to deliver ordnance accurately. Attention to parameters is important in order to avoid fouls and get actual bomb release near the desired altitude.

8.6.8.1. Cockpit Lightning. Because of the large reflective canopy of the F-16, nearly all of the bright spots inside the cockpit will reflect inside. These can distract your attention and make it hard to distinguish dimly lit ground targets. Keep your console and instrument panel lights at the minimum which will still allow you to read them.

8.6.8.2. HUD Brightness. Find an optimum HUD brightness level that suits the prevailing atmospheric condition and your individual vision. An overly bright HUD may not seem like a problem until you experiment and reduce the brilliance at which time the target may become much easier to see.

8.6.8.3. Radar Display Intensity. Set-up the REO using all three controls: intensity, contrast, and symbology. Since the radar display is not used in visual bombing you may want to simply turn the intensity down until it is nearly black while you work the range. The best radar display picture can be obtained by turning down the “contrast” first, then adjusting the other two controls.

8.6.8.4. Delivery Modes. The preferred mode for night visual surface attack is continuously computed impact point (CCIP). The dive toss (DTOS) mode can also be used, but it is better suited to long range, high altitude deliveries. CCIP offers the inherent advantage that the bomb fall line (BFL) always points down; perpendicular to the horizon.

Although you can still get the "leans" trying to steer out the pass, as long as the pipper is at the bottom of the HUD, pulling G will move the nose up. Thus, the CCIP symbology acts like an attitude indicator and aids in maintaining orientation. Continuously computed release point (CCRP) is the preferred delivery mode for targets which cannot be visually identified at night. The decision to accomplish level or loft deliveries should be based on desired delivery altitude, weapons effect, and target area considerations.

8.6.8.5. Aim-off/BFL Use. When you roll out on final you will have to rely solely on the HUD cues to establish an aim-off point and pipper placement. If you are accustomed to using a visual aim-off point on the ground, it will probably not be visible at night. Thus, you will need to roll out with the target about one-half to two-thirds of the way down the BFL. There is a strong tendency to pull the CCIP pipper up to the target and release high. While this technique is safe, it is not necessarily desirable because it causes larger miss distances. A controlled pass with release occurring at or near the preplanned release altitude is best. Do not over compensate for this tendency and press below planned release altitude. Above all, any time you feel uncomfortable, or you lose awareness of exactly where you are, abort the pass. DO NOT PRESS.

8.6.9. Flare Procedures. Although the F-16 is not certified for carriage of MK 24 flares, you may have a chance to drop using flares released by other aircraft. Flares are used for night close air support (CAS) and other missions where complete illumination of the target is required. Flare illumination makes it possible to fly by visual reference to the ground for attitude control, but a continual instrument cross-check is necessary, especially during recovery, changing armament switches, or when vertigo is suspected.

8.6.9.1. Flare Considerations. The LUU-2 flare will burn for 5 minutes and produce illumination rated at 2.0 million candlepower. A normal value for flare coverage is a circle with a 1 NM diameter. The flare descends 500 to 600 feet per minute. Directly beneath each burning flare, there is an area of subdued light caused by design characteristics. When two flares are dropped, the light overlaps and brightens the area of reduced intensity directly underneath each flare. Flares normally burn out at approximately 2,500 to 3,000 feet below ignition altitude. Attack conditions become marginal after the burning flare drops below 500 feet AGL due to the area of subdued light directly beneath the burning flare.

8.6.9.2. Environment. Sky and atmospheric conditions have a serious effect on the quality of flare illumination.

8.6.9.2.1. Weather. Low ragged overcast, fog, haze, or drizzle will cause flare light to be diffused and less effective. The probability of spatial disorientation is increased. Highly diffused light generally means no visible horizon and few orienting ground references; the total "world" is centered around the flare which creates a 3-dimensional sphere of light. This is referred to as the "milk bowl effect." Difficulty may be encountered in determining the aircraft's attitude and the vertical might appear to be in the direction of the flares. Use of flight instruments cannot be overemphasized.

8.6.9.2.2. Overcast. Flares burning under a medium or low overcast with good visibility will produce added light due to reflection. However, reflection can also produce deceiving perception problems. From a tactical standpoint, an aircraft is easily silhouetted against an overcast sky and readily discernible by enemy gunners.

8.6.9.2.3. Clear Skies. Clear weather, with moonlight and some ground illumination, provides excellent conditions for flare lighting, and attacks can be executed with minimum reference to flight instruments.

8.6.9.3. Flare Deconfliction. Flares can cause pilot disorientation and flight profiles must compensate for flare positioning and flight path deconfliction.

8.6.9.3.1. Flare Horizon. There is an apparent haze layer at the altitude of the burning flare. In a dive, as the aircraft approaches the flare's altitude, visibility becomes restricted; target and ground acquisition become more difficult. This problem can be reduced by releasing above or below, not level with the burning flare.

8.6.9.3.2. Flare Illusion. Flying below the altitude of burning flares is unwise but at times cannot be avoided. Extreme caution should be used as the flare may appear to be at a reasonably high altitude when actually it is on, or close to the ground.

8.6.9.3.3. Flare Positioning. The pilot must avoid any flares that drift into the approach path. Flares, as obstacles, usually generate a restriction to attack direction. Avoid the 6 o'clock low area to the flare ship. The pilot dispensing flares will offset accordingly for range wind and crosswind.

8.6.9.3.4. Flare Prediction. There will be approximately a 20- to 30-second delay from the radio call “FLARES AWAY” until you actually see the flares. Approximately 15 seconds are required for flares to reach maximum intensity after ignition. Observing night minimum recovery altitudes should keep you safely above spent flares. However, on some occasions, these empty flare chutes, referred to as “ghosts,” will ride thermals. They will be near or even above burnout altitude and downwind of the burnout point. Avoidance of these nearly invisible hazards is important during ordnance delivery and recovery. Also unseen, more dangerous, but less prevalent, are unignited flares suspended in their chutes. This type of dud (occurring at a rate of 12 to 15 percent) is always found below the ignited flares since it descends faster than an ignited flare. Avoid a dud flare by counting the lit flares and remaining above the altitude of the ignited flares dropped on the same pass.

8.6.9.3.5. Flare Monitoring. The RCO, upon hearing the flare pilot state the number of flares released, will have the primary responsibility for calling out dud flares. The RCO should also notify the flight of any flares burning on the ground. Flight members will assist in calling out the locations of hazardous flares. When the position of the lighted flares in the group indicates that the dud flare is in the proximity of the final approach, the pass will be aborted. Any time the RCO considers flares to be a hazard to safe flight, operations will cease.

8.7. Night Landing. Night landings are normally made from a precision approach. The approach should be flown the same as in the daytime. However, at night and in weather, the landing light may cause a distraction if it reflects off of the clouds. In this case, the landing light may be turned off until on short final. The landing light provides adequate reference for a normal landing. HUD intensity may have to be adjusted to adequately view symbology while still affording a clear view of the runway environment. Follow guidance IAW AFMAN 11-217, *Instrument Flight Procedures*, for landing out of instrument approaches and avoid the tendency to visually “duck under” the desired glide path. Visual references can be deceiving at night.

8.8. Night Refueling. Night refueling procedures are basically the same as day procedures, but standard night flying considerations apply. At night, you must be smooth to avoid inducing spatial disorientation. Perform the rendezvous like an IMC intercept, relying on GCI and your radar to complete the rendezvous. In the observation position, the forward nacelle light on the tanker may be distracting. Request the tanker to dim this light or fly a formation position that blocks the light with the tanker's wingtip. If any other light bothers you, ask the tanker to turn it off or down. As a courtesy, avoid making such requests when another flight member is on the boom. Pre-contact, contact, and post-contact procedures remain unchanged. Be prepared to transition to instrument flight if visual contact with the tanker is lost (lost wingman).

8.9. Night Emergencies. Emergencies at night are typically compounded at night due to the lack of visual references and reliance on the aircraft attitude and position instruments. Emergencies which effect aircraft lighting also have a dramatic affect on the pilot's ability to monitor aircraft performance and reference in-flight publications (checklist, pilot aid, approach plates, etc.). Always fly with a flashlight at night and ensure the batteries are operational prior to flight. In addition, an extra chemstick or other illumination device is also recommended for night flight. Emergencies which affect aircraft lighting (i.e., multiple generator failure, etc.) and game plans for handling these types of emergencies should be thoroughly briefed prior to night flight. Airfield lighting and instrument approaches at the divert bases should also be briefed.

8.10. In-Flight Distress Signals—Night Visual. The following in-flight distress signals (night visual) will be used only when the radio is inoperative and will be acknowledged by a steady light. Reference AFI 11-205, *Aircraft Cockpit and Formation Flight Signals*, for detailed in-flight distress signals.

- *Aircraft Emergency (Must Land As Soon As Possible)*: Signal escort aircraft by repeated intermittent flashes with a flashlight, then assume the wing position—this signal indicates a jet approach speed of 130 knots. If a higher approach speed is desired, the pilot must pause after the basic signal and then blink the flashlight at the top of the canopy—once for each 10-knot increase desired. The escort pilot will lead to the nearest suitable field, declare an emergency with the controlling agency, then fly a straight-in approach with the distressed aircraft on the wing. The distressed aircraft lands and the escort executes a go-around. On a straight-in approach, the escort aircraft pilot turns the position lights to BRIGHT/STEADY to alert the wingman to prepare to lower landing gear. The corresponding signal of execution will be for the escort aircraft pilot to return position lights to DIM/STEADY. If the aircraft is only equipped with a STEADY-BRIGHT light position, it will blink the lights for the alerting signal and for the execution signal.
- *Attention*: Attention should be attracted by whatever means of illumination are available (e.g., flashlight, position lights on-off, etc.).
- *Change Lead*: Pilot of the distressed aircraft holds the flashlight parallel with the canopy rail and sends a steady light while making a straight line from rear toward the front of the canopy.

- *Complete Electrical Failure (No Assist Aircraft Available)*: Procedures are the same as day visual signals.
- *Descent To Lowest Practical Altitude*: The pilot makes a rapid vertical movement with a flashlight.
- *Radio Inoperative (No Assist Aircraft Available)*: Follow day radio inoperative procedures.
- *Signal Acknowledgment*: Point a steady light from the flashlight at the signaling aircraft.
- *Night Approach-End Barrier Engagement Without Radio*: Fly parallel to the active runway, 1,000 feet AGL, flashing the landing light. Proceed as with day approach-end barrier engagement without radio.

CHAPTER 9

PROFICIENCY EXERCISES

9.1. Introduction. This chapter serves as a guideline to various proficiency exercises. These exercises are grouped into four sections: G-awareness training, aircraft handling exercises and maneuvers, fighter proficiency exercises, and low-altitude training exercises. A discussion of simulated flameout (SFO) approach considerations is also included.

9.2. G-Awareness. G-induced loss of consciousness (GLOC) is a serious problem. Contributing to the severity of this problem is the inability to accurately and reliably assess pilot G-tolerance and G-endurance. AFP 11-404, *G-Awareness for Aircrew*, provides comprehensive information on the physiology of G-awareness.

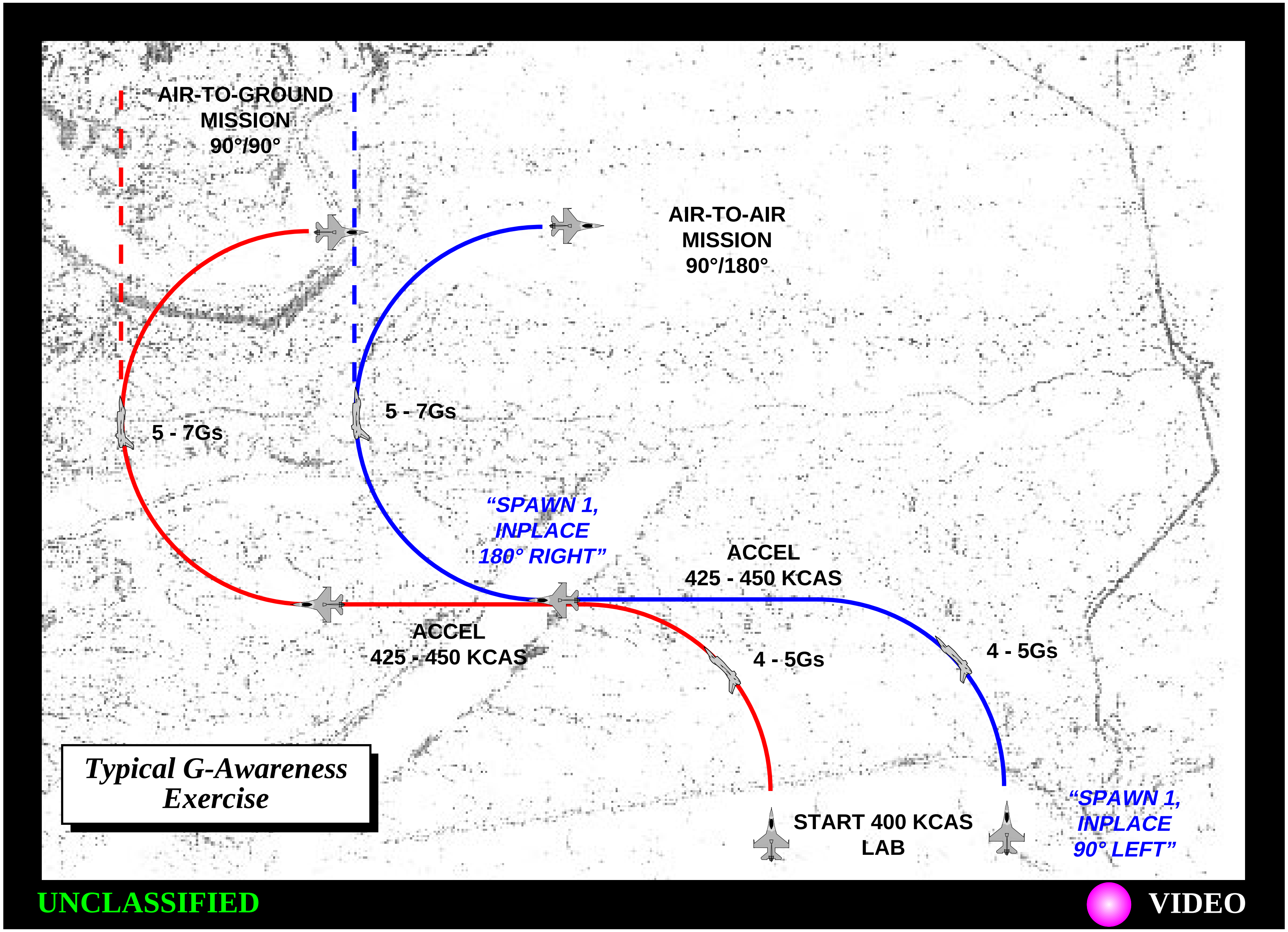
9.2.1. G-Tolerance. G-tolerance can be thought of as the ultimate G-level that can be maintained over a short period of time that still allows the pilot to employ the jet safely and effectively. However, if action is not taken to either improve the anti-G straining maneuver (AGSM) or reduce the G-load, rapid progression to GLOC will occur. G-tolerance is highly variable and dependent upon numerous additive factors.

9.2.2. G-Endurance. G-endurance, the maximum G-level that can be maintained over a longer period of time, is perhaps more important; especially considering the F-16's capability to sustain high G. G-endurance is highly dependent upon physical conditioning and "G-currency." Centrifuge studies have shown that layoffs of even a few weeks will result in significantly reduced G-endurance even though G-tolerance remains essentially unchanged. It is easy to see how this increased gap between G-tolerance and G-endurance could set a pilot up for GLOC.

9.2.3. G-Awareness Exercise. A dedicated G-awareness exercise should be conducted when required IAW AFI 11-214, *Aircrew, Weapons Director and Terminal Attack Controller Procedures for Air Operations*. **Figure 9.1.,** Typical G-Awareness Exercise, is an example of the exercise. The key to GLOC avoidance is pilot awareness; the pilot alone has the ultimate control over G-stress factors. For this reason, the G-awareness exercise is designed to heighten pilot awareness of the man-machine interface and the G-stresses of the mission at hand. As a minimum, the G-awareness exercise should be flown as follows:

- Establish adequate aircraft separation and airspeed to allow tactical maneuvering.
- Self-test the G-suit system for proper inflation, mindful of proper connections and leaks in the system.
- Film the exercise in head-up display (HUD) (if equipped) and in HOT MIC.
- With a smooth application of G (as in a tactical turn), perform a 4- to 5-G turn for 90 degrees (level to climbing). Use this opportunity to ensure proper operation of the G-suit and practice the timing and coordination of AGSM.

Figure 9.1. Typical G-Awareness Exercise.



- Reestablish airspeed and perform another 90 degrees (air-to-ground)/180 degrees (air-to-air) turn. Turn initially with 5 to 7 G's and then let off to a minimum of 3 to 4 G's during the last 90 degrees as energy bleeds off. Again use this opportunity to establish awareness for operating in the increased-G environment while practicing the AGSM.
- If aircraft limits or energy limits preclude completing the above at the prescribed G, then turns should be performed so as not to exceed aircraft limits.

9.2.4. G-Awareness Summary. The G-awareness exercise is not, nor is it meant to be, an assessment for G-tolerance or G-endurance. This exercise cannot protect you from GLOC. It can only afford the opportunity to test equipment, practice the AGSM and bring the G-environment to the forefront of your mind. G-awareness is a mindset, not a set of exercises to be done and forgotten. G-awareness must be practiced and observed throughout the mission. Remember GLOC incidents typically do not occur during canned “G-Awareness Exercises” when aircrews are physically and mentally prepared for the onset of G’s. They occur when pilots channelize their attention on some other facet of the mission, such as threat reactions, and place themselves in the high-G environment without preparing their bodies to do so.

9.2.5. Anti-G Straining Maneuver. The AGSM is the best G-defense measure available to aircrew members. Equipment measures (anti-G suit, COMBAT EDGE, reclined seat, etc.) were never meant to replace the AGSM, only aid it. The AGSM must be properly performed by pilots in order to gain maximum benefit. It is imperative to realize the AGSM should be performed under all G-loading, only the intensity of the AGSM should be varied to match the particular G-load. The intent is to ingrain into the subconscious the ability to automatically apply the proper AGSM anytime G-loading is applied or anticipated. This will build the instinctive reaction required by your body to ensure you do not get caught behind the G-loading and become a GLOC statistic. Additionally, an instinctive, properly executed AGSM will serve to benefit you with increased combat capability as it allows you to maximum perform the aircraft in the combat arena. It is also the best defense against fatigue that will degrade the performance and make you even more susceptible to GLOC on your next engagement.

9.2.5.1. Performing the AGSM. The AGSM consists of two components, muscle tensing and a cyclic breathing technique which must be performed in the proper sequence. Performing one without the other may significantly reduce the effectiveness of the strain. The following are the sequential steps required to properly perform an effective AGSM:

- Anticipate the G.
- Tense ALL lower body muscles including the gluteus (butt) and abdominals.
- Take a deep breath, hold against a closed glottis (throat), and bear down to generate chest pressure.
- Hold the chest pressure against the glottis until on top of the “G.”
- Take a very short, quick breath every 2.5 to 3.5 seconds (the duration and volume of air exchanged is roughly equivalent to the amount you could exhale and inhale through a “soda straw” in 0.5 to 1 second).

- Minimize communication and do not relax until the aircraft is really unloaded.
- Muscle tensing increases usable blood volume and return of blood to the heart. The harder the muscles contract, the greater the reduction in the tendency for blood to pool. Tensing of all skeletal muscles, especially lower body and abdominals, help to “push” blood back to the heart.
- It is important to maintain muscle tension throughout the G-load. The muscle strain intensity may be varied depending on the G-load, but tension must continue as long as the G-load is maintained. The muscle strain must be maintained continuously, even when breathing.
- An effective AGSM increases heart output pressure. The greater the pressure generated in the chest, the greater the resultant blood pressure to the eyes and brain.

9.2.5.2. Common Errors in Performing the AGSM.

- Failure to translate proper AGSM knowledge into a skill that is integrated into other flying skills. The AGSM must be consciously practiced correctly in the aircraft until its performance becomes automatic and correct. This takes a lot of discipline and practice.
- Developing good chest pressure but failing to tense the lower body musculature or relaxing the lower body muscles while still under G, the blood will immediately pool in the extremities making it very difficult for blood to return to the chest even at moderate G and may result in almost instantaneous GLOC or severe visual loss at best, depending on the G.
- Failure to anticipate the G. Performance of the AGSM should begin, ideally, just before the aircraft is loaded. Failure to do so will result in the aircrew member either trying to catch up on the AGSM (a very dangerous practice) or having to unload in order to buy time to catch up.
- Failure to maintain chest pressure (loss of air). Occurs while talking or whenever the strain is audible. As air is lost from the chest the amount of pressure generated falls. This directly reduces blood pressure to the brain. If air loss is heavy, as might occur with speech, the subsequent loss of blood pressure in the brain may result in GLOC without the prior warning of visual loss. Other causes of air loss are “groaning” (letting the air escape slowly) and trying to hold the chest pressure by sealing the lips rather than with the throat.
- Holding your breath less than the required 2.5 to 3.5 seconds results in lower average blood pressure in the brain than would be obtained otherwise (G-tolerance is reduced) and fatigue is accelerated.
- Holding your breath longer than 3.5 seconds. The increased chest pressure impedes return of blood to the chest where it is available to the heart. If blood return to the chest is blocked for 4 to 5 seconds, the heart may have insufficient blood to pump.

- Exhaling too much air or taking too long to complete the exhalation and inhalation cycle while under G, particularly common during rapid onset. Results in a reduced ability to develop chest pressure and may significantly shorten the breath-holding time.
- Performing a strain with the intensity necessary to stay awake at 9 Gs while actual G-load is much lower. This will result in early fatigue and increased potential for GLOC in subsequent engagements. The intensity of the AGSM may be graduated in relation to the level of G. It is always safe to overestimate the intensity of the strain, it is always unsafe to underestimate the intensity required. Ideally, the intensity of the straining maneuver will match the G-level.

9.2.5.3. AGSM Assessment. Assess the AGSM effectiveness during mission debriefings. This assessment should not be limited to the G-awareness exercise. It is imperative to evaluate the AGSM after the pilot has had time to fatigue, as this is usually when the AGSM breaks down and GLOC occurs.

9.2.5.3.1. Fly the tactical portion of all basic missions (basic fighter maneuvers [BFM], surface attack, air combat maneuvering [ACM], etc.,) in HOT MIC to enable assessment of the AGSM. Intercom volumes should be set at a level which is comfortable for the aircrew, but still allows assessment of breathing and AGSM technique in the debrief. For high task sorties dissimilar air combat tactics [DACT], composite force, opposed surface attack tactics [SAT], etc.,) it is highly desirable for aircrews to fly in HOT MIC. The purpose is to identify breakdowns in the AGSM which commonly occur during high task portions of a mission.

- HUD should be selected with camera “ON” (if applicable).
- Listen for a preparatory inhalation just before or as the G is loaded. If it is not there, the pilot may already be behind the G.
- Listen for exhalation sounds or talking during the G-onset. This signifies loss of air from the chest and reduced efficiency of the strain and G-tolerance. Additionally, the pilot is likely to be behind the G and will have trouble catching up. This may cause the pilot to either unload some of the G or sharply increase the intensity of the strain (usually audible). The latter may be a result of recognition of vision loss. Ideally, the first breath should be held until the desired G-level is reached or 3 seconds, whichever occurs first.
- Listen for the first exhalation. It should be short and immediately followed by a quick inhalation. The end of the inhalation may be noted by a sudden grunt sound or a sudden absence of breathing sounds. Total time for the breath ideally should be 0.5 second, but in no case should be longer than 1 second.
- If breath intervals are greater than 3.5 seconds, return of blood to the chest may be impeded reducing G-tolerance. If breath intervals are 4 seconds or longer, there is an increased risk of GLOC.

9.2.5.3.2. Ideally, after the inhalation, breath sounds should not be heard for 2.5 to 3.5 seconds. If breath sounds are more rapid, average chest pressure is lower and

G-tolerance is negatively affected. As G-tolerance is negatively affected, the pilot will have to work harder at any given G-load. Fatigue during the engagement, or especially in subsequent engagements, will most likely become apparent. This may be evidenced by even more rapid breathing or breathless, gasping sounds. Observation of the G-load at these times may provide evidence that the pilot is apparently working too hard for the G or is unable to maintain the G necessary for the tactical situation.

9.2.5.3.3. Talking at G may be hazardous depending on the individual and the G-load. If talking is required, it should be in very short bursts accomplished during the breathing phase of the AGSM. However, the need to talk should be weighed carefully against the need to stay awake.

9.2.5.4. AGSM Summary. Remember, the same AGSM should be performed anytime G is applied, only the intensity of the maneuver is varied. Therefore, the AGSM should also be assessed under relatively low intensity G such as air-to-surface sorties.

9.3. Aircraft Handling Exercises and Maneuvers. The following exercises and maneuvers are designed to expose the pilot to various parameters within the F-16’s flight envelope. When executed correctly, they will explore the aircraft's flight envelope and reinforce awareness of aircraft performance. Minimum altitudes for the Horn Awareness Series, Confidence Maneuvers, and Advanced Handling Maneuvers is 10,000 feet AGL. Reference the applicable exercises or maneuvers for minimum and recommended entry altitudes.

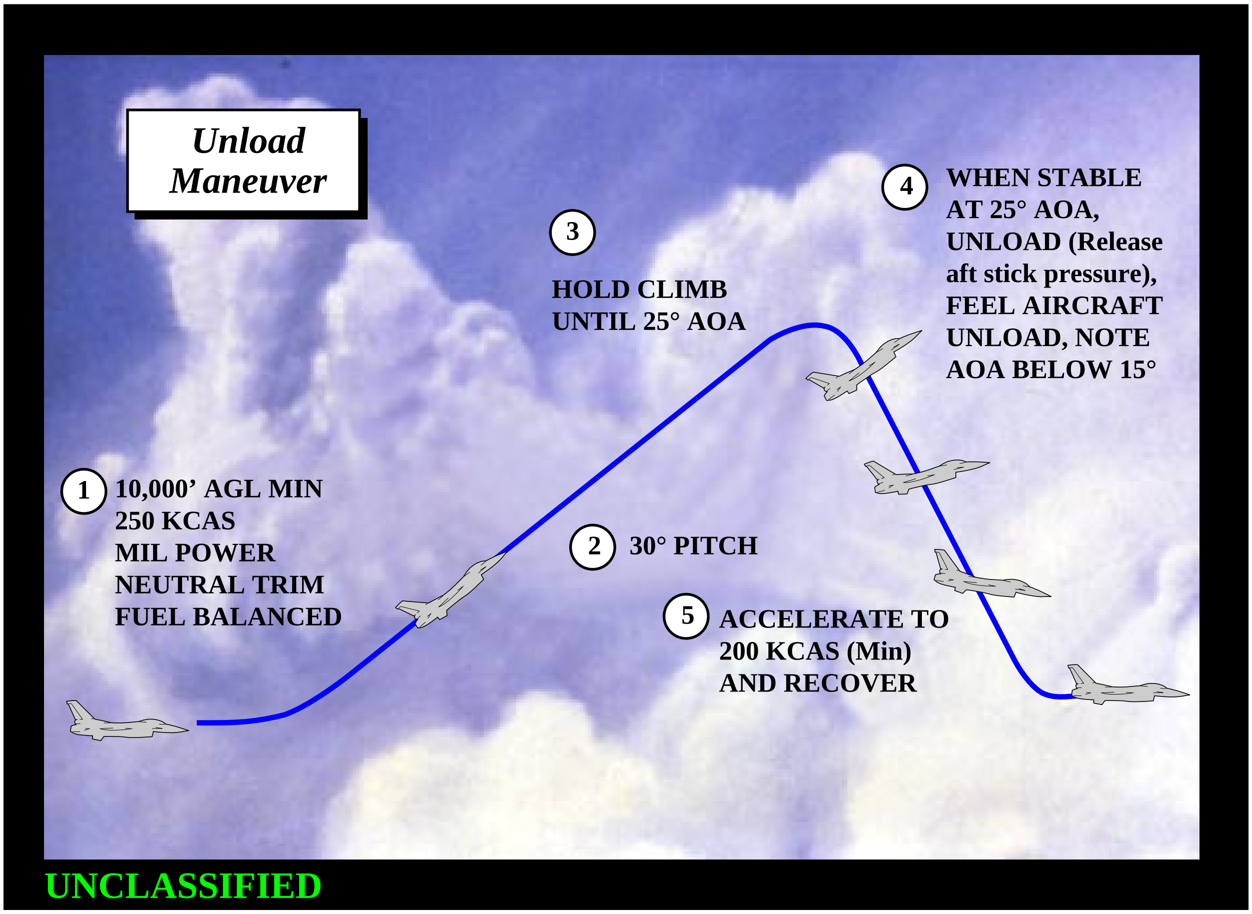
9.3.1. Horn Awareness and Recovery Training Series. Horn Awareness and Recovery Training Series (HARTS) of maneuvers is flown to train recovery procedures from high-pitch attitude, slow airspeed conditions normally signaled by the horn. It is designed to be flown initially in sequence as a series. These controlled maneuvers will place you into a position in which you may unintentionally find yourself while engaged in ACM. This exposure will train you to use the proper recovery procedures should you find yourself in this situation during future flying. There are five individual maneuvers in the series. The pitch attitude for all these maneuvers should be set and maintained on the attitude direction indicator (ADI) not the flight path marker (FPM); reference to the HUD flight path results in an increasing attitude as the angle of attack (AOA) increases. The key to flying these maneuvers is to use finesse in bringing the nose to the horizon with minimum airspeed loss. If the recoveries are delayed due to slow pilot response, failure of the warning horn, or if abrupt inputs are made, a departure is possible. It should be emphasized that the roll to the horizon should be made smoothly avoiding buffet, and smoothly stopped before aft stick is applied. Smooth application of aft stick (if needed) is essential. If the nose is not moving toward the horizon, aft stick should be smoothly applied (up to full command) to get the nose moving and keep it moving. If the nose is very high and the airspeed is very slow, a rapid pitch rate downward may develop. In this case, when the nose approaches vertical downward, a good technique is to apply slight forward stick pressure to slow the pitch rate and protect against overshooting the AOA limiter. See the Dash 1 for more information.

NOTE: HARTS maneuvers are to be flown by CAT I loaded aircraft only.

WARNING: For maneuvers 4 and 5, departure susceptibility significantly increases with wing tanks at entry airspeeds between 300 and 325 knots calibrated airspeed (KCAS) or in any configuration with entry bank angles less than 10 degrees.

9.3.1.1. Unload Maneuver. HARTS Series #1 (**Figure 9.2.**, Unload Maneuver).

Figure 9.2. Unload Maneuver.



9.3.1.1.1. Objective. To learn the proper technique required to unload the aircraft and recognize an unloaded condition.

9.3.1.1.2. Setup. 10,000 feet AGL or above, 250 knots calibrated airspeed (KCAS), MIL power, fuel balanced, neutral trim (1 G).

9.3.1.1.3. Description. Pull up to 30 degrees pitch with approximately 2 to 3 G's. Initially, slight forward pressure is required to maintain pitch attitude. At approximately 150 KCAS, aft stick is required until reaching the limiter. When the aircraft is stable at 25 degrees AOA, unload (release aft stick pressure) and note aircraft unload (check AOA, should be below 15 degrees). Hold the unload until the aircraft accelerates to 200 KCAS minimum. At 200 KCAS, initiate recovery to level flight.

9.3.1.1.4. Comments. This unload is the key to any safe recovery. This maneuver is to teach you the proper way to unload the F-16 so you can safely roll the aircraft regardless of airspeed. Because the F-16 is flown with neutral trim (set to 1 G), a release of aft stick pressure should bring the AOA to less than 15 degrees. A proper unload at slow airspeed and high AOA is to release the aft stick pressure. This unload may take 2 to 3 seconds and will make you feel light in the seat. On the first practice maneuver, look at the AOA tape, note the AOA and the unload feel. This maneuver should be practiced until the recovery can be accomplished without looking inside the cockpit.

9.3.1.2. Nose-High Recovery Maneuver. HARTS Series #2 (**Figure 9.3.**, Nose-High Recovery Maneuver).

9.3.1.2.1. Objective. To systematically practice the unload maneuver and rolling to the nearest horizon while unloaded.

9.3.1.2.2. Setup. 10,000 feet AGL minimum, 350 KCAS, MIL power, fuel balanced, neutral trim.

9.3.1.2.3. Description. Pull up to 60 degrees pitch with approximately 2 to 3 G's and hold. Slight forward stick pressure is required to hold the pitch attitude. At 200 KCAS, unload (release stick pressure) and roll the aircraft inverted to the nearest horizon using positive but smooth control inputs. Stop the roll with aileron. When wings level inverted, smoothly apply sufficient aft stick to pull the nose below the horizon. Once the nose is below the horizon, unload and accelerate to 200 KCAS. At 200 KCAS, roll upright and recover.

NOTE: IAW Dash 1 procedures, if altitude is a factor during the recovery, allow airspeed to increase to a minimum of 150 knots, unload the aircraft to less than 1 G, smoothly roll upright and recover to level flight.

9.3.1.3. Horn Demonstration Maneuver. HARTS Series #3 (**Figure 9.4.,** Horn Demonstration Maneuver).

9.3.1.3.1. Objective. To demonstrate and check the operation of the low airspeed/ nose-high position warning horn and to practice proper recovery procedures at the horn.

9.3.1.3.2. Setup. 10,000 feet AGL or above, 300 KCAS, MIL power, fuel balanced, neutral trim.

9.3.1.3.3. Description. Pull up to 50 degrees of pitch with approximately 2 to 3 G's and hold. Allow airspeed to decay until warning horn sounds or 100 KCAS, whichever occurs first. At the horn (or 100 KCAS minimum), unload (release stick pressure); then smoothly roll inverted to the nearest horizon. Stop the roll, then smoothly apply sufficient aft stick to track the nose below the horizon. With the nose below the horizon, unload and accelerate to 200 KCAS. At 200 KCAS, roll upright and recover.

Figure 9.3. Nose-High Recovery Maneuver.

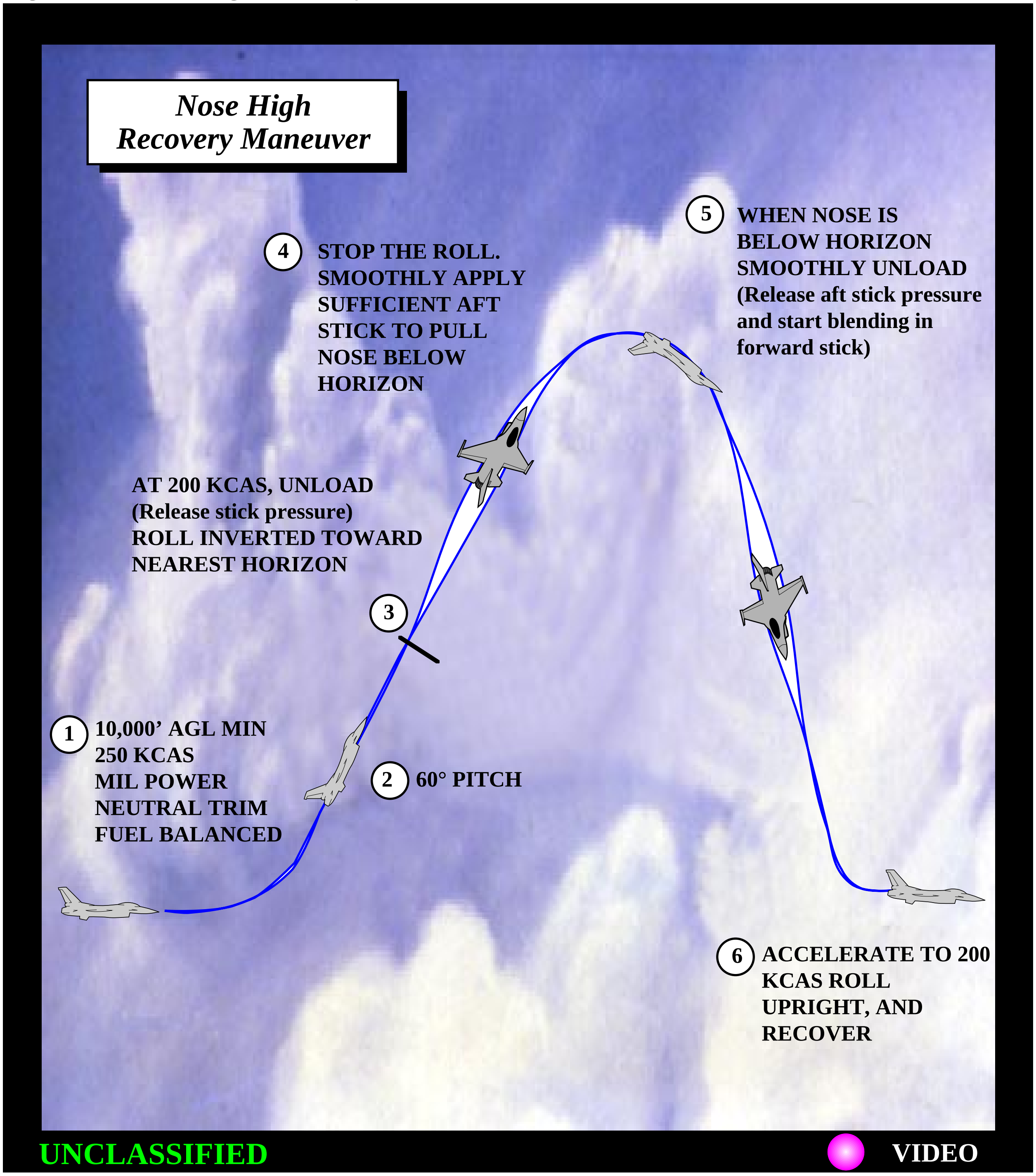
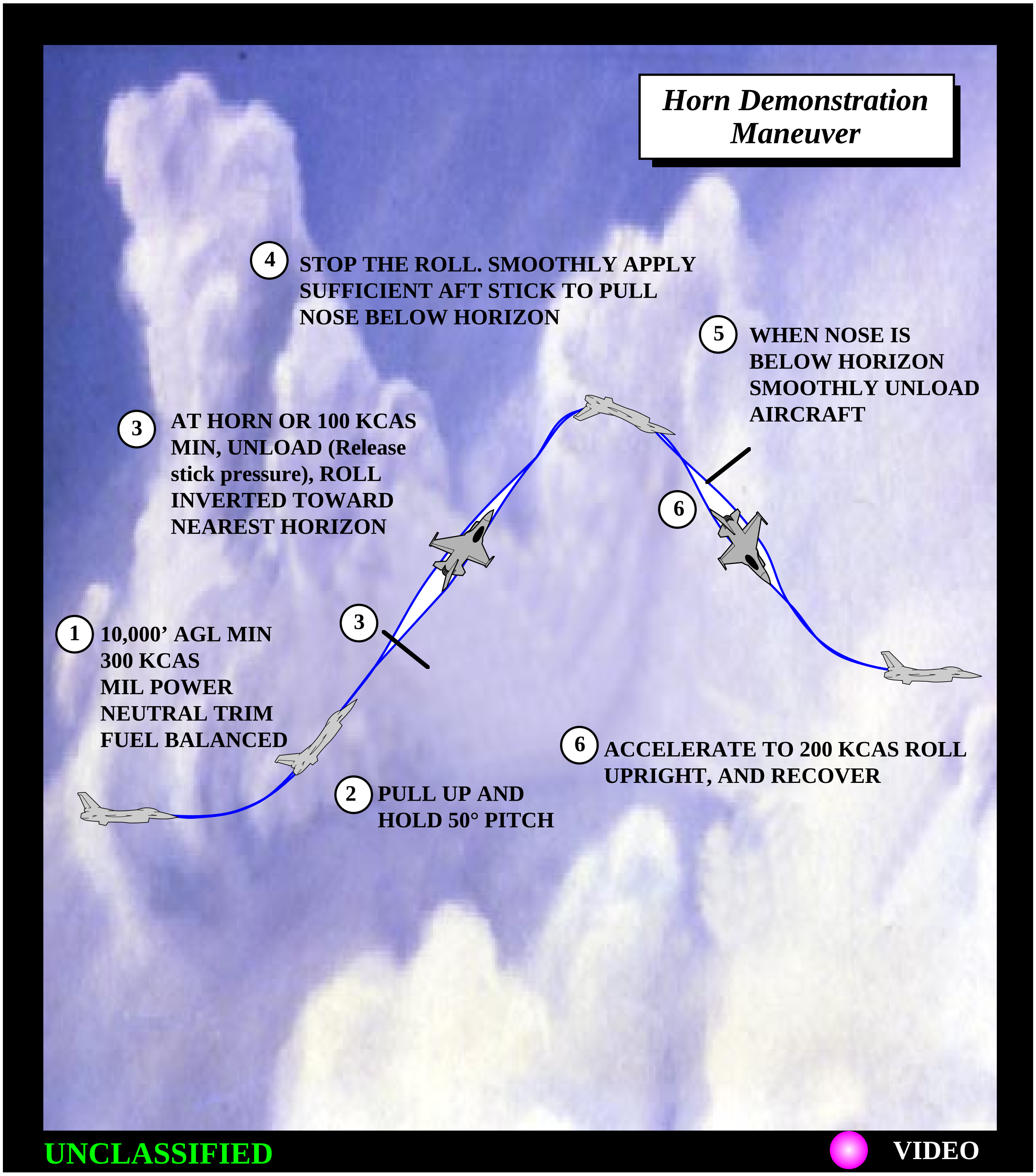


Figure 9.4. Horn Demonstration Maneuver.



9.3.1.3.4. Comments. The horn should come on between 120 KCAS and 130 KCAS. A secondary objective of this maneuver is to verify that the horn works prior to flying the horn recovery maneuvers. This should be the first time you hear the horn during this series of maneuvers. If the horn does not come on prior to 100 KCAS, discontinue this series of horn recovery maneuvers and write up the horn after the flight. Smooth but positive control inputs and attention to unload cues are imperative. The aircraft rolls smoothly while unloaded; however, the roll must be positively stopped when inverted prior to smoothly applying aft stick to avoid assaulting both flight control limiters simultaneously.

9.3.1.4. Horn Recovery Maneuver, 50 to 70 Degrees. HARTS Series #4 (**Figure 9.5.,** Horn Recovery Maneuver, 50 to 70 Degrees).

NOTE: If flown in an F-16AM, configured with wing tanks, entry airspeed will be 250 to 275 KCAS.

9.3.1.4.1. Description. Roll into 10 to 20 degrees bank and apply full aft stick (limiter). When the horn sounds (or 130 KCAS, whichever occurs first) unload (release aft stick pressure); then roll the aircraft inverted toward the nearest horizon. Stop the roll, then smoothly apply sufficient aft stick to track the nose below the horizon. With the nose below the horizon, unload and accelerate to 200 KCAS. At 200 KCAS, roll upright and recover.

9.3.1.4.2. Comments. The 250 KCAS entry airspeed will cause the horn airspeed to occur prior to extremely high pitch attitudes if back stick is applied fairly quickly to the AOA limiter. Pitch attitudes of 50 to 70 degrees are typical, with the horn activating at 150 KCAS to 170 KCAS. The low initial bank angle is necessary because bank angle tends to increase as the pull-up progresses. If the pull-up is started with more than 30 degrees bank, the horn may not come on because overbanking causes insufficient pitch attitude to reach the horn envelope (45 degrees nose high). Full aft stick is used to ensure the aircraft is on the limiter at the horn. This will prevent an inadvertent pitch pulse at low airspeed which could cause an AOA overshoot.

NOTE: Based on flight test experience, departure resistance and desired learning objectives should not be adversely affected with any of the following store combinations:

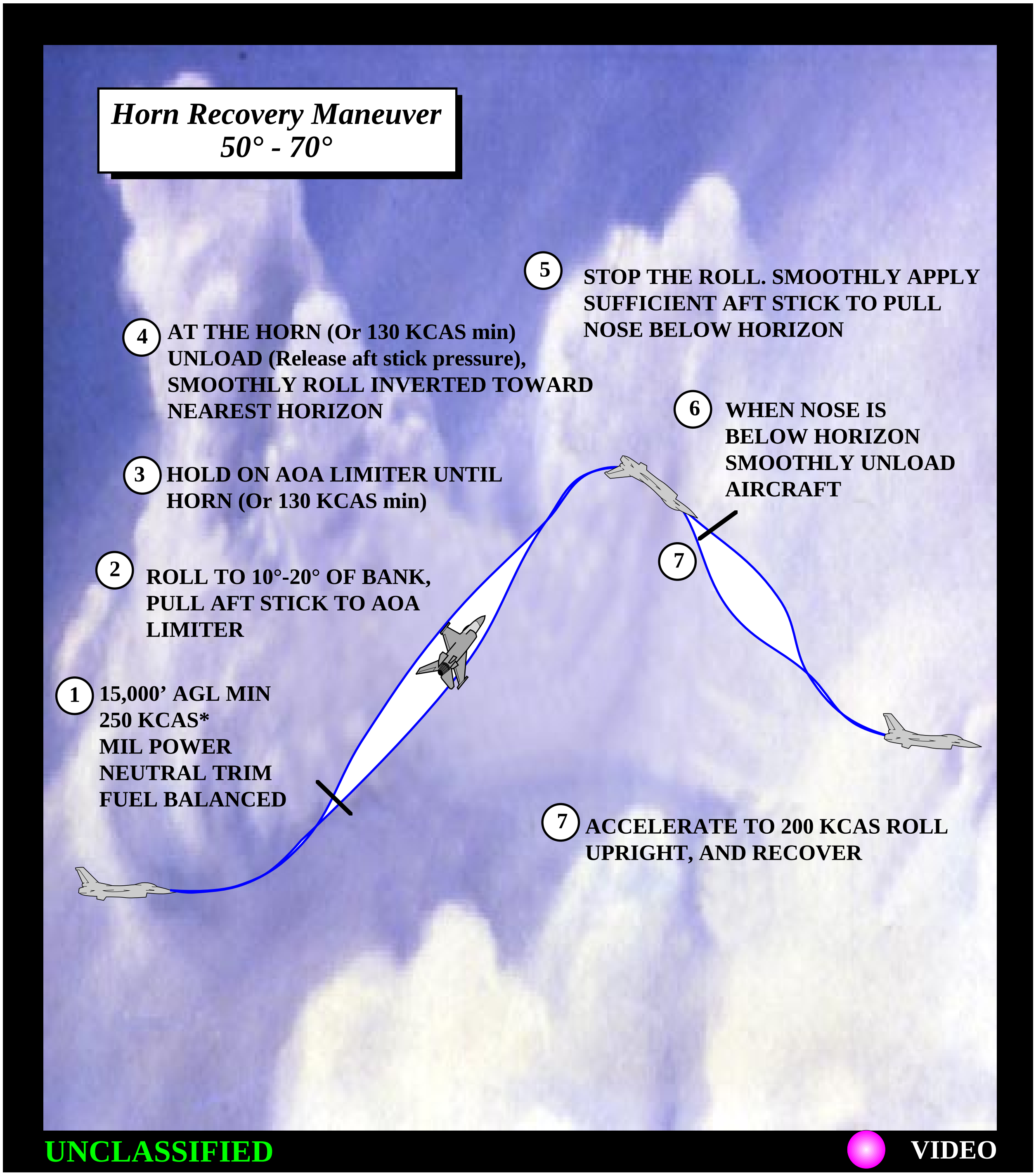
- One AIM-9 missile at station 1 or 9.
- Two AIM-9 missiles at stations 1 and 9.
- A centerline pylon at station 5.
- A centerline fuel tank.

WARNING: Departure susceptibility increases significantly if airspeed and bank angle parameters are not met.

9.3.1.4.3. Objective. Practice recovery at the horn from nose high, high AOA, low airspeed conditions.

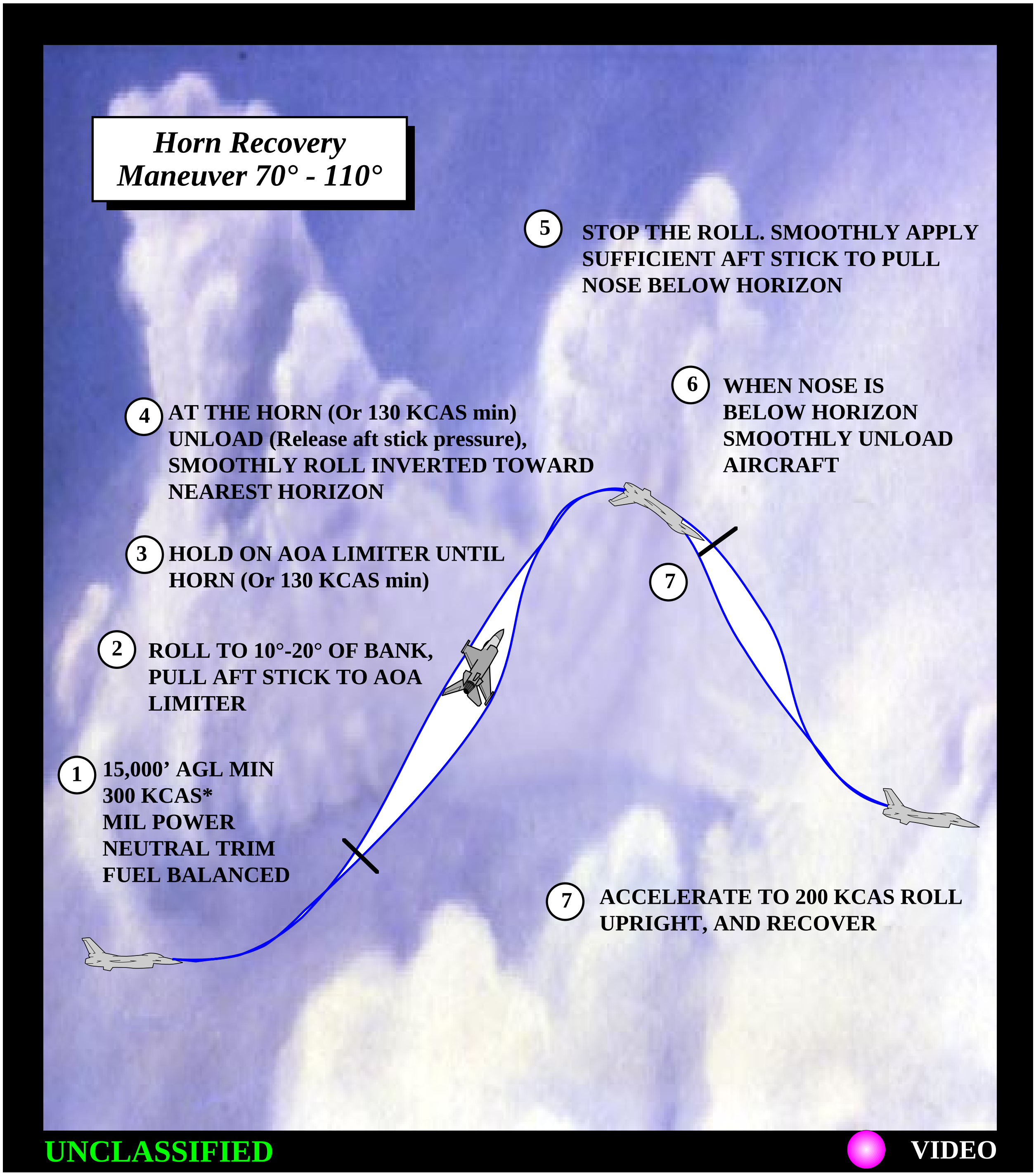
9.3.1.4.4. Setup. 15,000 feet AGL or above, 250 KCAS, MIL power, fuel balanced, neutral trim.

Figure 9.5. Horn Recovery Maneuver, 50 to 70 Degrees.



9.3.1.5. Horn Recovery Maneuver, 70 to 110 Degrees. HARTS Series #5 (**Figure 9.6.**, Horn Recovery Maneuver, 70 to 110 degrees).

Figure 9.6. Horn Recovery Maneuver, 70 to 110 degrees.



NOTE: If flown in an F-16AM/BM, configured with wing tanks, entry airspeed will be 250 to 275 KCAS. This may result in a lower pitch attitude than desired but is necessary due to departure tendencies when entered at higher airspeeds.

9.3.1.5.1. Objective. Practice recovery at the horn from very nose high, high AOA, low airspeed conditions.

9.3.1.5.2. Setup. 15,000 feet AGL or above, 300 KCAS, MIL power, fuel balanced, neutral trim.

9.3.1.5.3. Description. Roll into 10 to 20 degrees of bank and apply full aft stick (limiter). When the horn sounds (or at 130 KCAS, whichever occurs first), smoothly unload (release aft stick pressure); then roll the aircraft inverted toward the nearest horizon. Stop the roll, then smoothly apply sufficient aft stick to track the nose below the horizon. With the nose below the horizon, unload and accelerate to 200 KCAS. At 200 KCAS, roll upright and recover.

9.3.1.5.4. Comments. This maneuver is identical to the previous one except for higher entry airspeed. The entry airspeed will allow the nose to rise to 70 to 110 degrees pitch before horn activation. The horn should come on in the 180 KCAS to 200 KCAS range. Unload the aircraft before any amount of roll input is made, then smoothly initiate sufficient aft stick to get the nose moving below the horizon. The rest of the recovery technique is exactly the same as for the previous maneuver.

NOTE: Based on flight test experience, departure resistance and desired learning objectives should not be adversely affected with any of the following store combinations:

- One AIM-9 missile at station 1 or 9.
- Two AIM-9 missiles at stations 1 and 9.
- A centerline pylon at station 5.
- A centerline fuel tank.

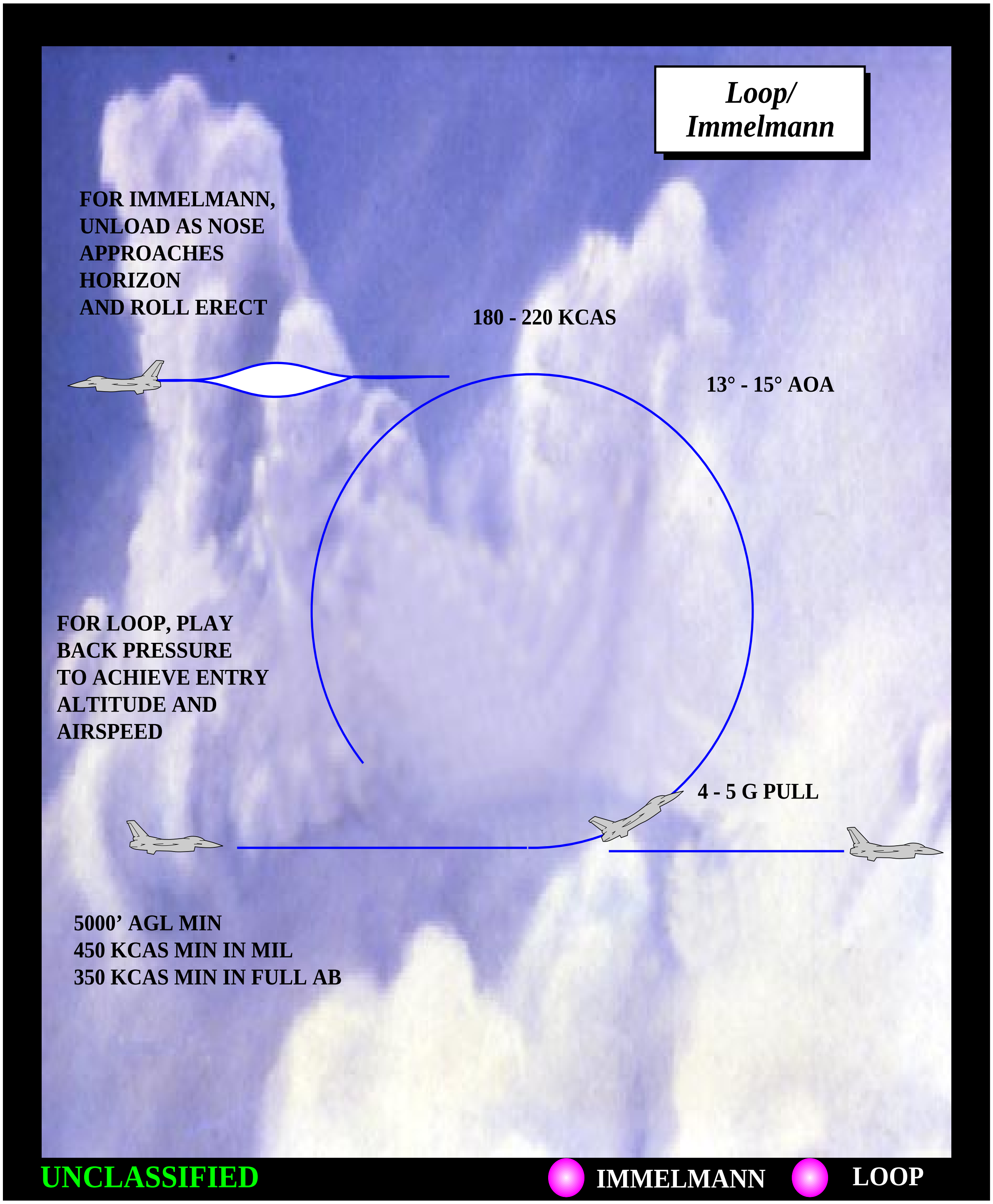
WARNING: Departure susceptibility increases significantly if airspeed and bank angle parameters are not met.

9.3.2. Aerobatics.

9.3.2.1. Loop. At 450 KCAS minimum, above 5,000 feet AGL (10,000 feet AGL recommended), with MIL power, begin a wings-level, 4- to 5- G pull (**Figure 9.7.,** Loop/ Immelmann). As airspeed dissipates across the top, maintain smooth pitch rate. The AOA should be 13 to 15 degrees (at 14 degrees AOA you should feel light buffeting). As the nose comes back through the horizon inverted (approximately 180 to 220 KCAS) and airspeed begins to build, ease off the back pressure and play the G to arrive back in level flight near entry altitude and airspeed. In a tanked F-16B/D, expect to lose 1,000 feet or 50 knots attempting to achieve entry airspeed or altitude, respectively. If AB is used, enter at 350 KCAS minimum. Use sufficient G on the back side of the maneuver to preclude excessive airspeed buildup.

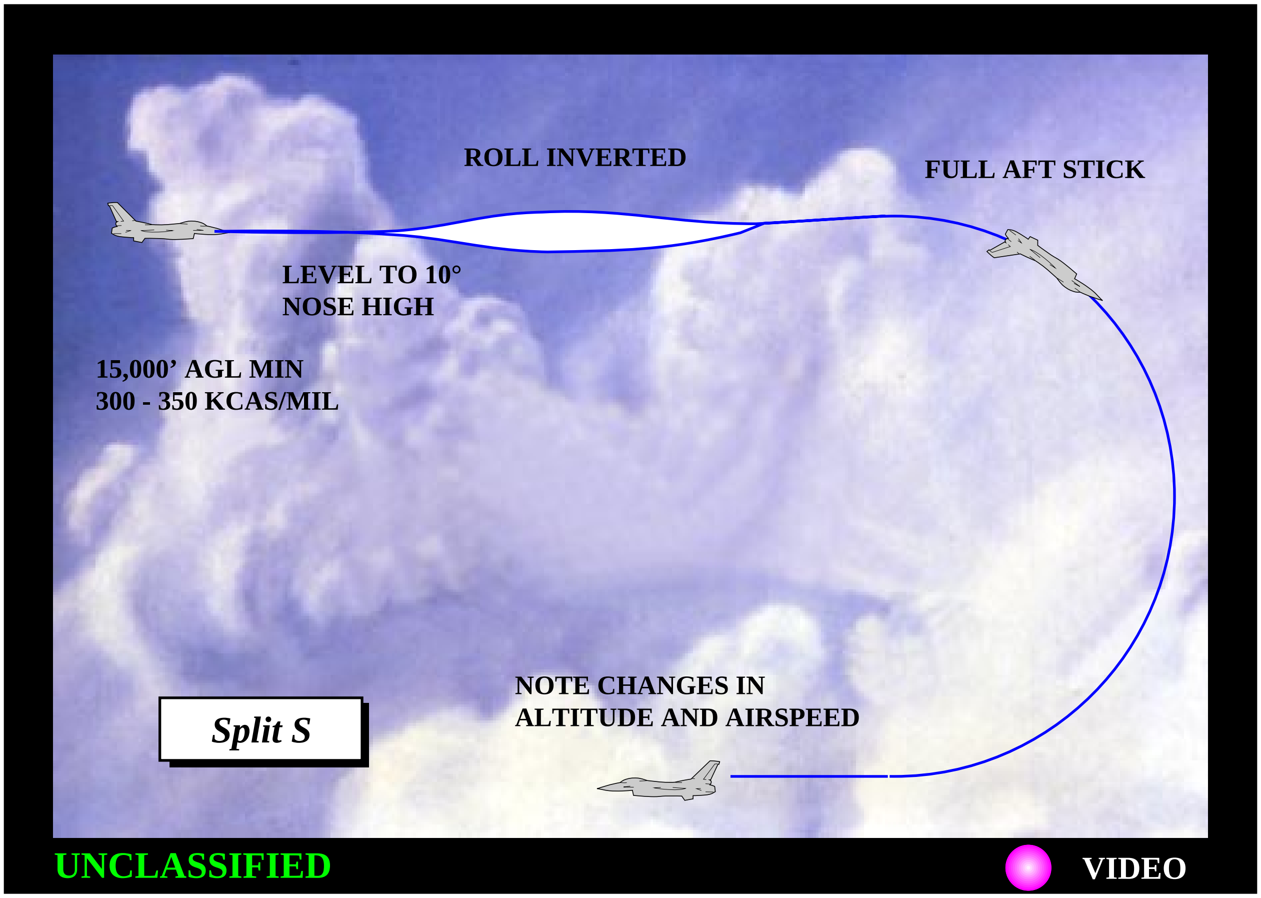
9.3.2.2. Immelmann. At 450 KCAS minimum, above 5,000 feet AGL (10,000 feet AGL recommended), with MIL power, begin a wings-level, 4- to 5-G pull (**Figure 9.7.,** Loop/ Immelmann). As airspeed dissipates across the top, maintain a smooth pitch rate. The AOA should be 13 to 15 degrees (at 14 degrees AOA you should feel light buffeting). As the nose approaches the horizon inverted, unload and roll the aircraft to arrive upright wings-level in level flight (FPM on the horizon line). If AB is used, enter at 350 KCAS minimum. Roll out at the top remains the same.

Figure 9.7. Loop/Immelmann.



9.3.2.3. Split "S." Enter at or above 15,000 feet AGL, between 300 to 350 KCAS, MIL power, level to 10 degrees nose high (**Figure 9.8.**, Split "S"). Roll unloaded to wings-level inverted and smoothly apply full aft stick. Terminate the maneuver in straight and level flight above 5,000 feet AGL (note change in altitude and airspeed).

Figure 9.8. Split "S."



9.3.2.4. Cloverleaf. Pick a point 90 degrees off the nose in the direction of turn. At 450 KCAS minimum, above 5,000 feet AGL, (10,000 feet AGL recommended), MIL power, begin a wings-level 3- to 4-G pull (**Figure 9.9.**, Cloverleaf). At approximately 45 degrees nose high, decrease back pressure and start a rolling pull in the direction of the 90-degree point. The roll rate should be planned to reach a wings-level inverted position with the nose on the horizon at the 90 degrees point (airspeed approximately 200 to 220 KCAS). Continue the maneuver as in the backside of a loop, playing the G's to arrive near the entry airspeed and altitude.

9.3.3. Advanced Handling Maneuvers.

9.3.3.1. Pitchback. This maneuver is a hard, then optimum turn (approximately 13 degrees AOA) beginning with the lift vector above the horizon and ending with it below (**Figure 9.10.**, Pitchback). Enter above 5,000 feet AGL at 400 KCAS or higher. Select full AB, roll into 40 to 50 degrees of bank and simultaneously begin a 5- to 7-G climbing turn. After 90 degrees of turn, bank should be approximately 90 degrees. After 180 degrees of turn, it should be 135 degrees. At this point, the maneuver ends with a gain of 3,000 to 5,000 feet and a minimum airspeed of 300 KCAS. Reduce G during the maneuver to preserve airspeed.

Figure 9.9. Cloverleaf.

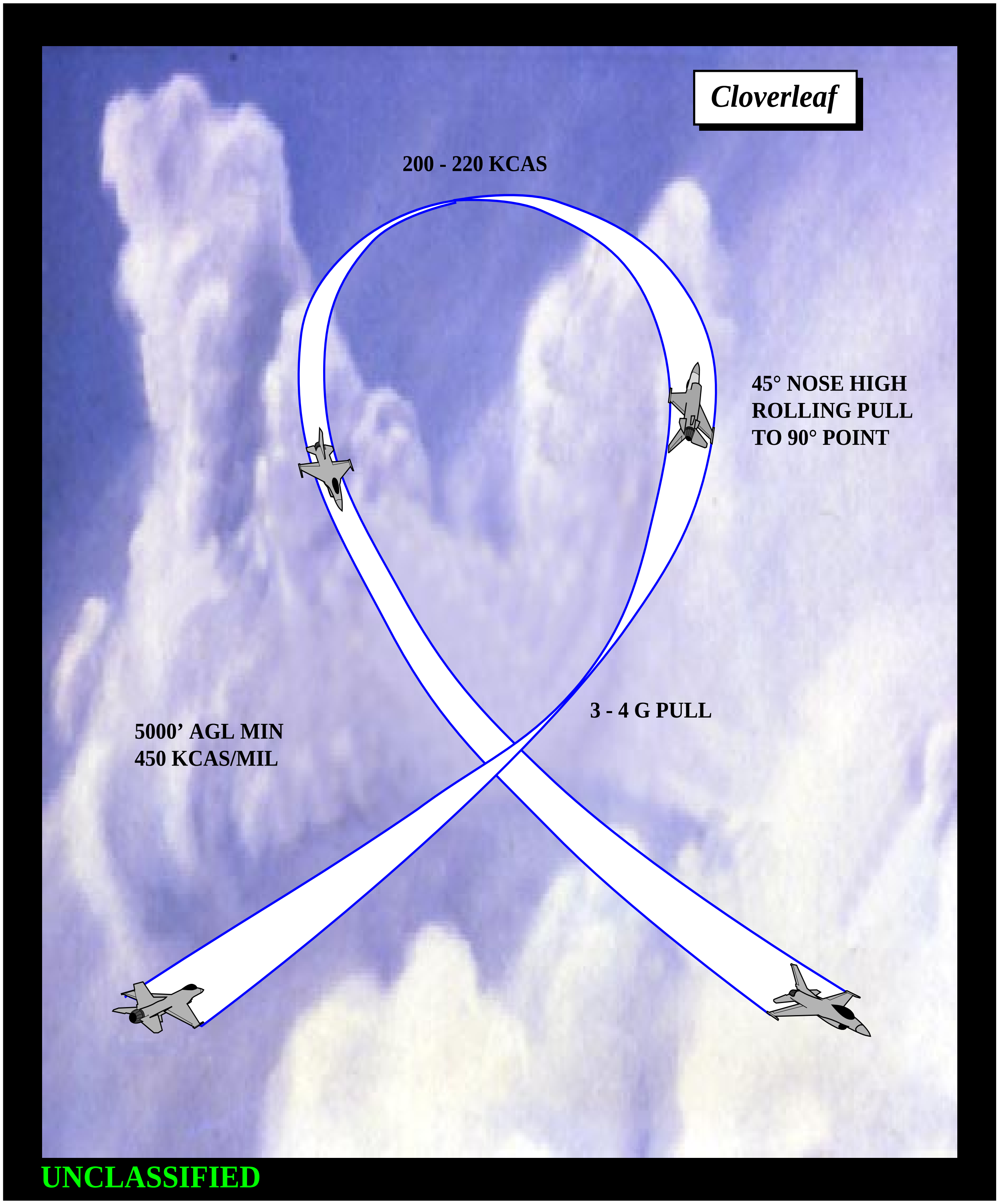
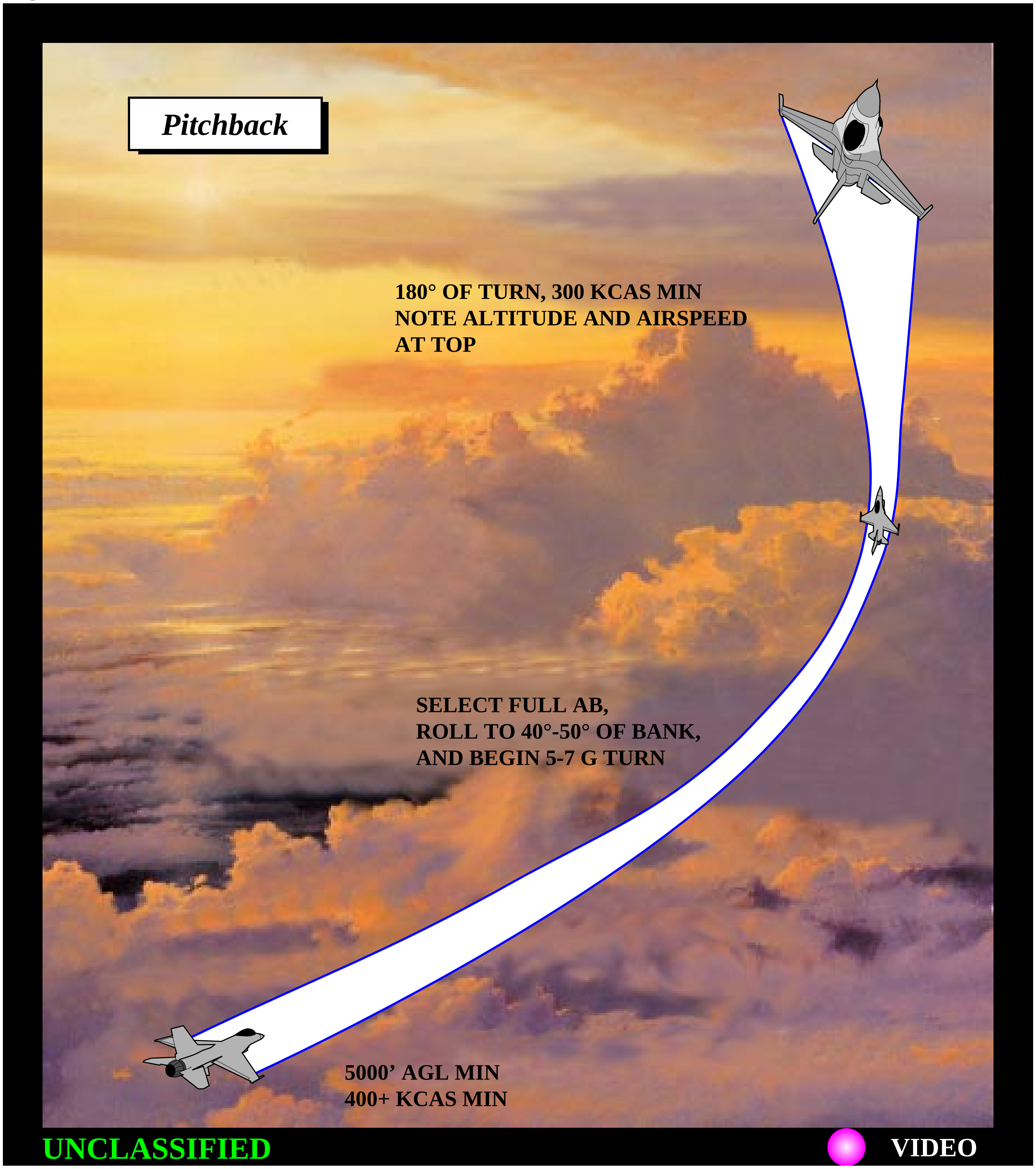
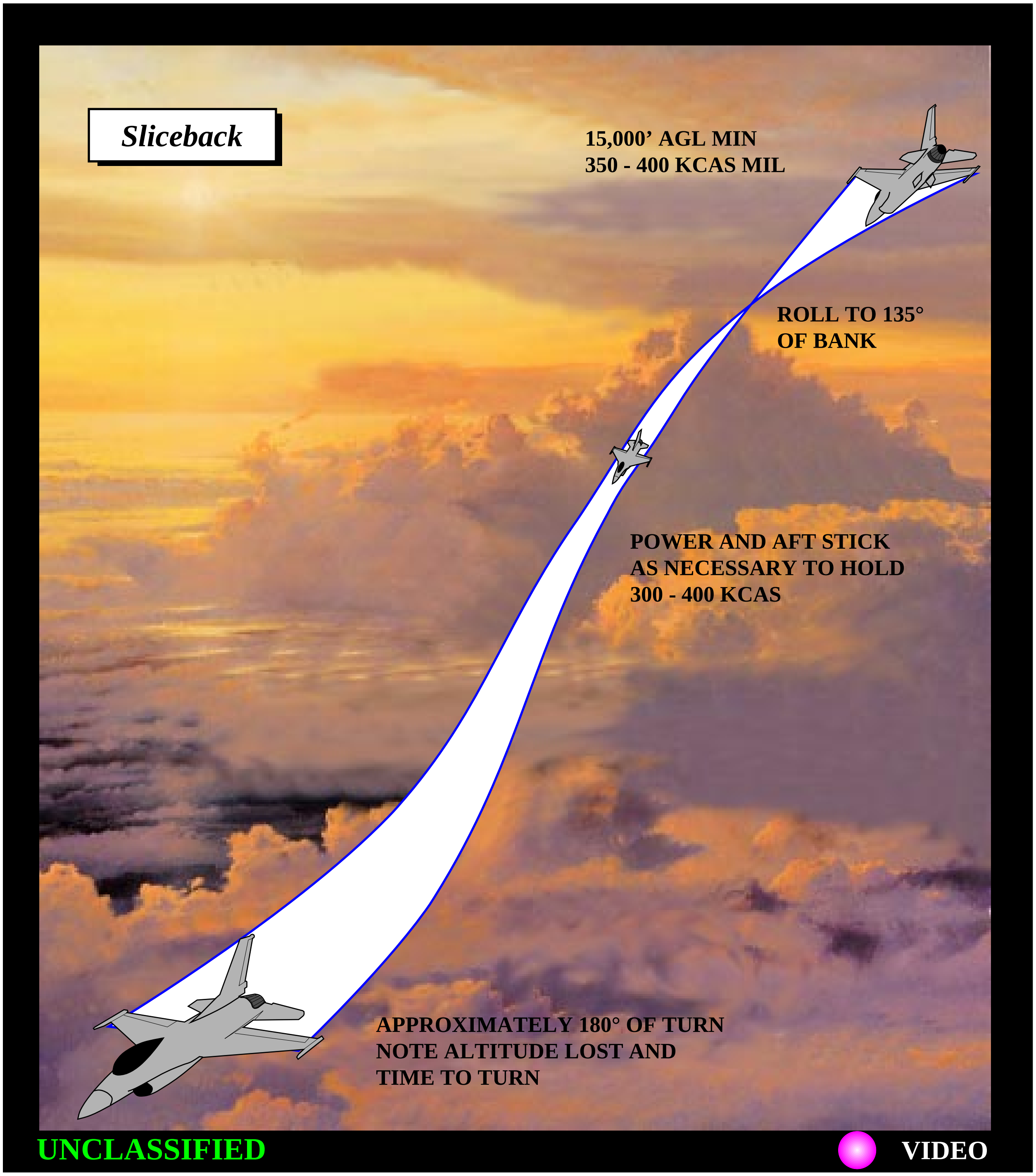


Figure 9.10. Pitchback.



9.3.3.2. Sliceback. Enter at or above 15,000 feet AGL, between 350 to 400 KCAS, MIL power. Initially roll into 135 degrees of bank and smoothly increase aft stick as required to maintain 300 to 400 KCAS (**Figure 9.11.**, Sliceback). The maneuver is completed upon

Figure 9.11. Sliceback.



roll out in level flight after approximately 180-degree of turn. The sliceback is a Split "S" type maneuver designed to make a 180-degree descending turn while minimizing turn time and optimizing energy state. If speed is above 400 KCAS and a descending turn is required, reduced power and speed brakes may be necessary if minimum turn radius and altitude loss are desired.

9.3.3.3. Reversals/Rolling Maneuvers Demonstration. Enter above 10,000 feet AGL at 300 to 400 KCAS with fuel balanced. Establish a 4- to 5-G turn in MIL power (**Figure 9.12.,** Reversals/Rolling Maneuvers). When the instructor calls “Reverse,” reverse the direction of turn while maintaining G loading. This maneuver demonstrates the characteristics of a vector roll and its affects on energy state. It is used in air-to-air training by attackers to prevent a flight path overshoot and by defenders, as a last ditch maneuver, to force one. Full lateral stick pressure produces maximum roll rate at any AOA and airspeed, while limiters decrease roll rate below 250 KCAS or above 15 degrees AOA. Rudder is not required at any AOA/airspeed.

9.3.3.4. Vertical Recovery Demonstration. The objective is to demonstrate the effect of the 30 degrees seat when extremely nose high, G and pitch rate available at low airspeed and high AOA when on the pitch limiter, and ability to pull down through the vertical without fear of getting the nose buried (**Figure 9.13.,** Vertical Recovery). Set up at 10,000 feet AGL minimum, 400 KCAS minimum, MIL power, and fuel balanced. Make a wings-level pull up at approximately 4 G's and establish a vertical attitude on the ADI. Note how the 30 degrees seat angle creates an impression of being more than pure vertical. At 250 KCAS, smoothly apply and hold full aft stick pressure to establish a pitch rate towards the horizon. Continue to hold full aft pressure while the aircraft passes nose down vertical. When the nose is 30 degrees below the horizon, unload and accelerate to 200 KCAS minimum before completing recovery to wings-level flight. During this demonstration, the airspeed will decrease, and with full aft stick, the G will drop to 1.6 to 1.7 but the limiter, controlling AOA, will still permit a rapid pull through approximately 240 degrees of pitch change.

Figure 9.12. Reversals/Rolling Maneuvers.

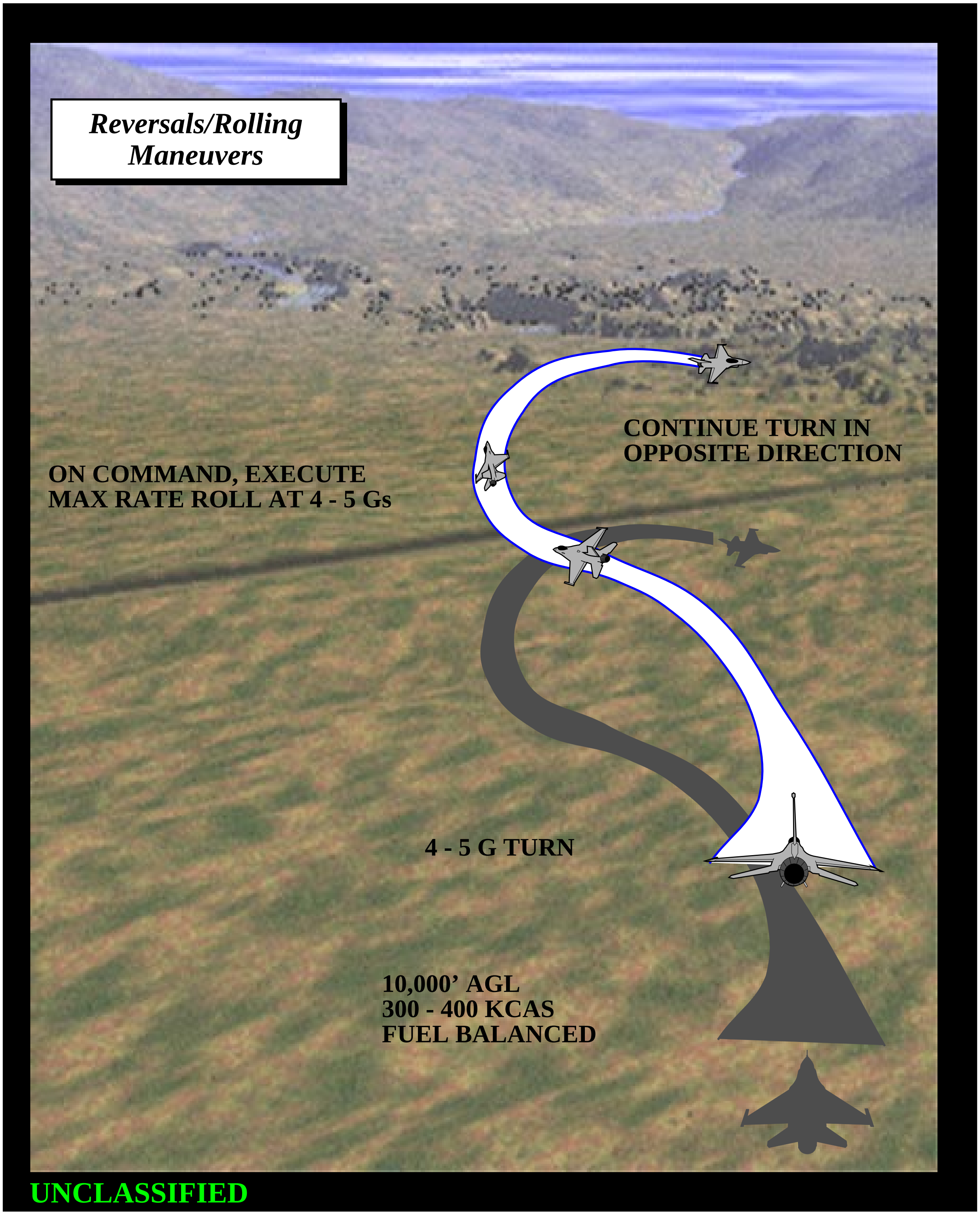
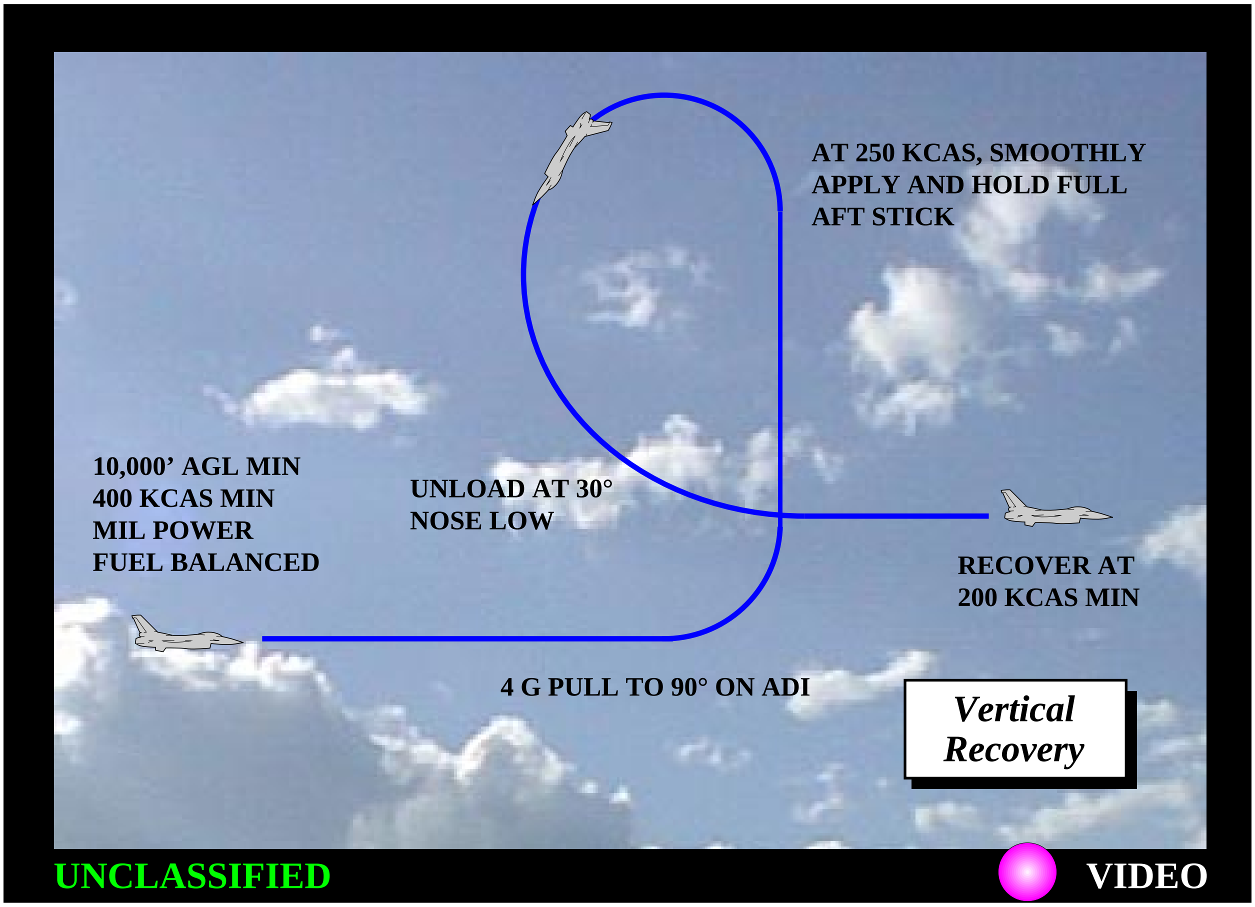


Figure 9.13. Vertical Recovery.



NOTE: If 200 KCAS occurs at any altitude above 60 degrees pitch and other than true vertical, immediately execute the nose-high recovery maneuver described in **Figure 9.3.**, Nose-High Recovery Maneuver.

NOTE: If full aft stick pressure is inadvertently released during the recovery, smoothly reapply aft stick pressure only if required to keep the nose moving toward the horizon. If you have released the stick and the nose is still moving toward the horizon, do not reapply the stick.

9.3.4. Departure Indicators. The previously discussed maneuvers are a series of events designed to develop a “feel” for the F-16's handling characteristics. Additionally, the HARTS teaches the proper procedures to recover from a nose-high, low airspeed situation and avoid departure from controlled flight. While these are planned events, situations may occur which place you in similar circumstances with less recovery or reaction time then optimum. Several, but not all-inclusive, departure indicators are:

- A sensation of lateral side forces developing.
- Uncommanded aircraft movements (pitch and/or roll).
- AOA pegged at +32 degrees if upright or -5 degrees if inverted.
- Airspeed oscillating below 200 KCAS.

9.3.5. Dive Recovery Maneuver. Dive recovery capability is a function of pullout load factor, dive angle, true airspeed, and flight control system (FLCS) limiting. In a nose-low, low airspeed (below approximately 350 KCAS) situation, rolling wings-level, pulling to the limiter, retracting speed brakes, and selecting and maintaining MIL or AB thrust minimizes altitude lost. If airspeed is above 350 KCAS, rolling wings-level, pulling to the limiter, opening the speed brakes, and selecting and maintaining IDLE thrust reduces altitude lost. During a supersonic dive recovery at or above 1.4 Mach, the engine will remain at or near MIL thrust with the throttle at IDLE. As airspeed decreases below 1.4 Mach, thrust decreases, but will not decrease to idle thrust until airspeed is below 0.9 Mach (GE engine) or 0.84 Mach (PW engine). Altitude required for recovery in this situation may be significantly greater than anticipated. Loss of consciousness in this situation could be fatal. During a recovery, constantly assess altitude remaining versus altitude required. If disoriented or unable to determine attitude from the HUD, reference the round dials. If altitude is critical, the FLCS may not allow sufficient G/AOA for recovery. Unnecessarily delaying the ejection decision could preclude safe ejection prior to ground impact.

9.3.6. Dive Recovery Practice. To practice dive recoveries, attain an entry altitude of 15,000 feet AGL minimum, an airspeed of 350 KCAS (high-speed recovery) or 250 KCAS (low-speed recovery), power as required, and establish a 60-degree dive with less than 30 degrees of bank. Prior to 10,000 feet AGL and 550 KCAS (high-speed recovery) or 350 KCAS (low-speed recovery), recover by rolling wings-level, set throttle and speed brakes as appropriate, and apply maximum G until the aircraft is in level flight or climbing. Refer to TO 1F-16-1-1 dive recovery charts for additional data. While practicing this maneuver, do not “snatch” the G's to the maximum G onset rate since this increases the potential for a GLOC incident.

9.4. Fighter Proficiency Exercises. Maneuvering during proficiency exercises achieves basic objectives of line of sight (LOS) pictures, switchology drills, recognizing weapons opportunities, and weapons employment. The following exercises can be modified to refine or work on specific objective areas.

9.4.1. Gun Exercises. The following gun exercises are designed to practice pipper placement, pipper control, symbology awareness, and maneuvering in respect to another aircraft. While accomplishing these exercises, do not fail to continually cross-check range and overtake. Do not get padlocked on the green stuff and forget what is happening spatially around you. Think situational awareness (SA). Know your airspeed, altitude, and fuel.

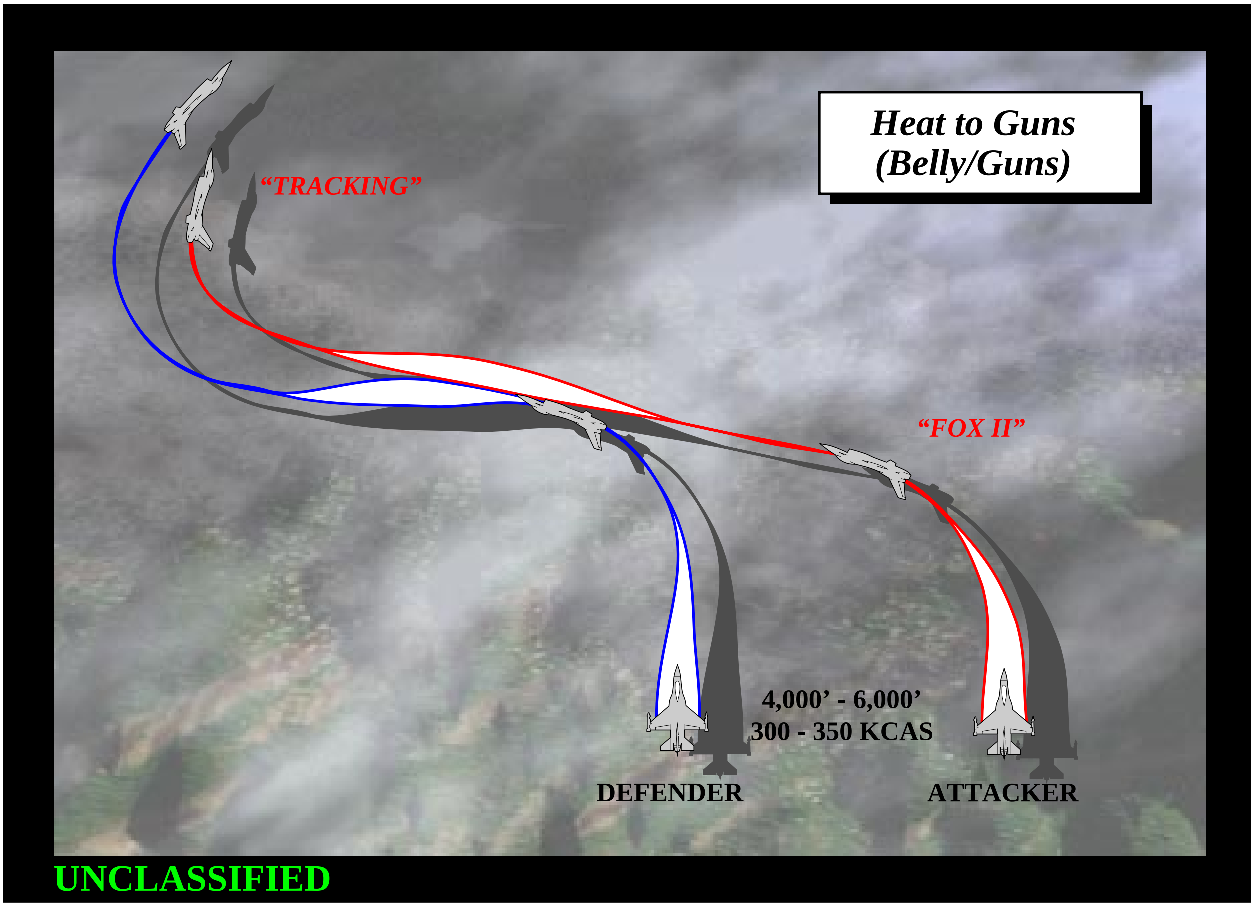
9.4.2. Ranging Exercise. Start with the offender 1.0 NM to 1.5 NM in trail with the defender holding 300 to 350 knots and the offender with an airspeed advantage. The offender then closes to minimum range (bubble) with either aircraft calling range in 1,000- to 500-foot increments. The offender can correct the defenders range calls with a radar lock. Note size comparisons, gun weapons employment zone (WEZ) ranges for M-56 or PGU-28 rounds, and different angle off pictures with a turn by the defender.

9.4.3. Offensive Heat-to-Guns Exercise. Begin the exercise by flying 4,000 to 6,000 feet line abreast and 300 to 400 KCAS (**Figure 9.14.,** Heat-to-Guns.). Each aircraft will call “ready” and the flight lead will initiate the exercise. The defender will then make a 3- to 4-G, 45- to 60-degree level turn away from the offender. The offender will attempt and call a valid

AIM-9 shot during this turn. After the check turn is completed, the defender will reverse turn following the offenders "FOX II" call or as required. The offender will then close for a tracking shot, or a snapshot/separation, as briefed. The offender will call tracking on each gun attempt while the defender may change plane slightly after the first tracking call. The exercise will terminate with 2 to 3 valid gun tracks or after achieving pre-briefed objectives.

NOTE: This exercise will allow the attacker to practice short range AIM-9 employment on a non-maneuvering target and continuous gun employment under varying flight conditions (level, climbing, descending, accelerating, decelerating, and rolling). The defender must maintain a tally and remain predictable through the exercise.

Figure 9.14. Heat-to-Guns.

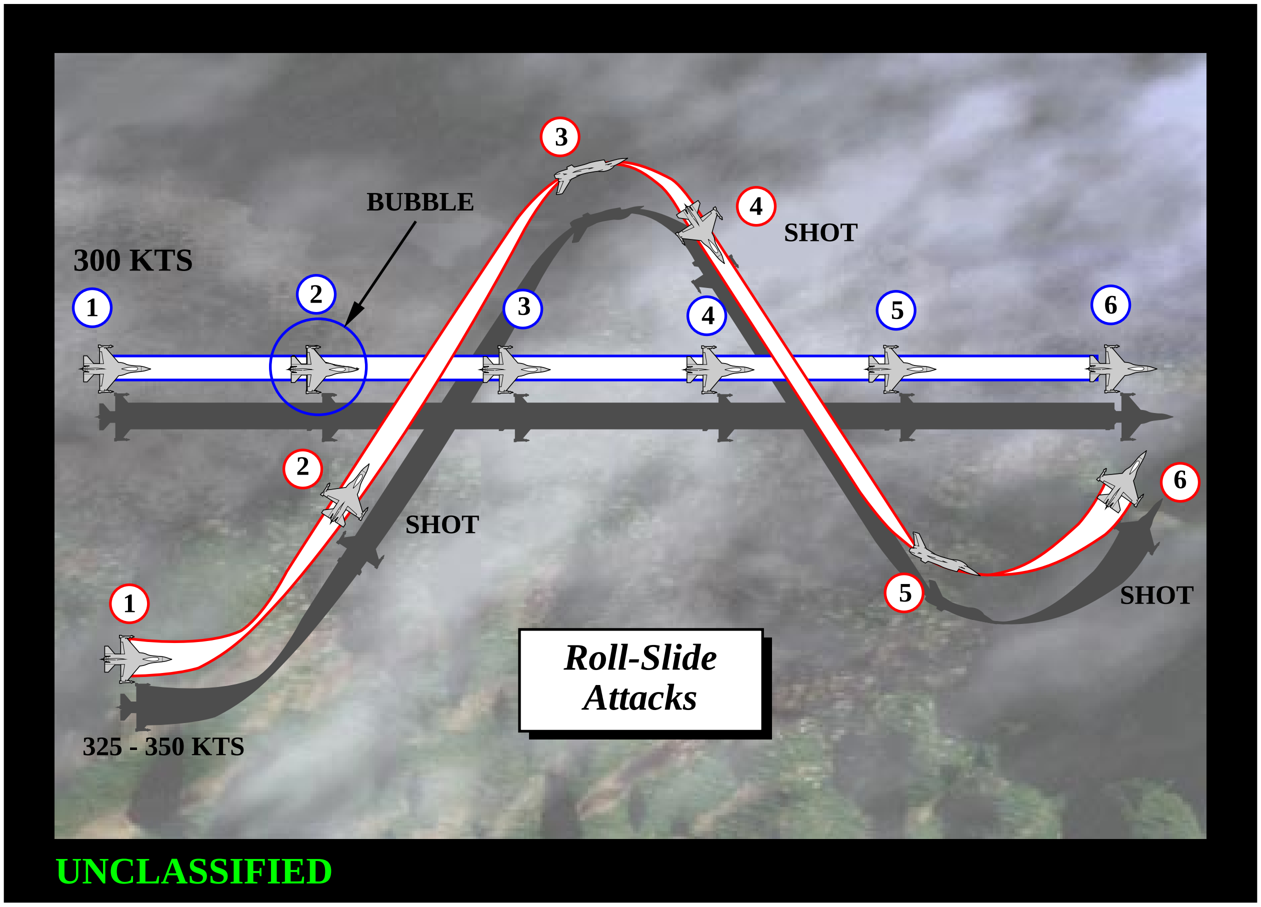


9.4.4. Defense Ranging Exercise. The same starting parameters are used as in **Figure 9.14.**, Heat-to-Guns. After the Fox II or reverse turn, the offender can call any combination of the following to build sight pictures: lag pursuit plus range (gun cross in lag), pure pursuit plus range (gun cross on), lead low (inside gun range with low plane established), lead high (inside gun WEZ with a slightly high plane established, and lead on (when in gun parameters). Two leafs of the exercise may be accomplished by having both aircraft roll out, the offender extending for range and airspeed, and then a "reverse turn" call to set parameters the same as the initial check turn. On the second leaf, the defender will now call "NO RANGE CALLS" lag, pure, lead low, lead high, and lead on. One Jink maneuver may also be added when lead on is observed by the defender on the second leaf.

NOTE: This exercise builds defensive sight pictures to recognize when in gun envelopes to help in Jink timing. The defender should note various ranges and the amount of lead required by the offender to be in a gun WEZ.

9.4.5. Roll-Slide Attacks Exercise. Defender sets speed at 300 to 350 KCAS with the offender 4,000 to 6,000 feet and slightly forward of line abreast (5 to 10 degrees). (**Figure 9.15.**, Roll-Slides Attacks.) The offender maintains an airspeed advantage. At the begin maneuver call, the defender flies a non-maneuvering flight path. The offender performs roll-slide gun attacks by initially pulling in plane towards the defender until forward LOS is seen and attempting a radar lock. The offender then rolls out and sets gun cross in defender plane of motion (POM). The offender should now concentrate on taking a valid gunshot and *not* saddling up for a steady track on the defender. The trigger should be on based on LOS rate to put bullets on the defender and then reposition by rolling out, going high if required to avoid the bubble and extending out to line abreast to execute the same maneuver. On each subsequent pass, the offender should climb and descend slightly to recognize in plane pictures from a high or low position off the defender.

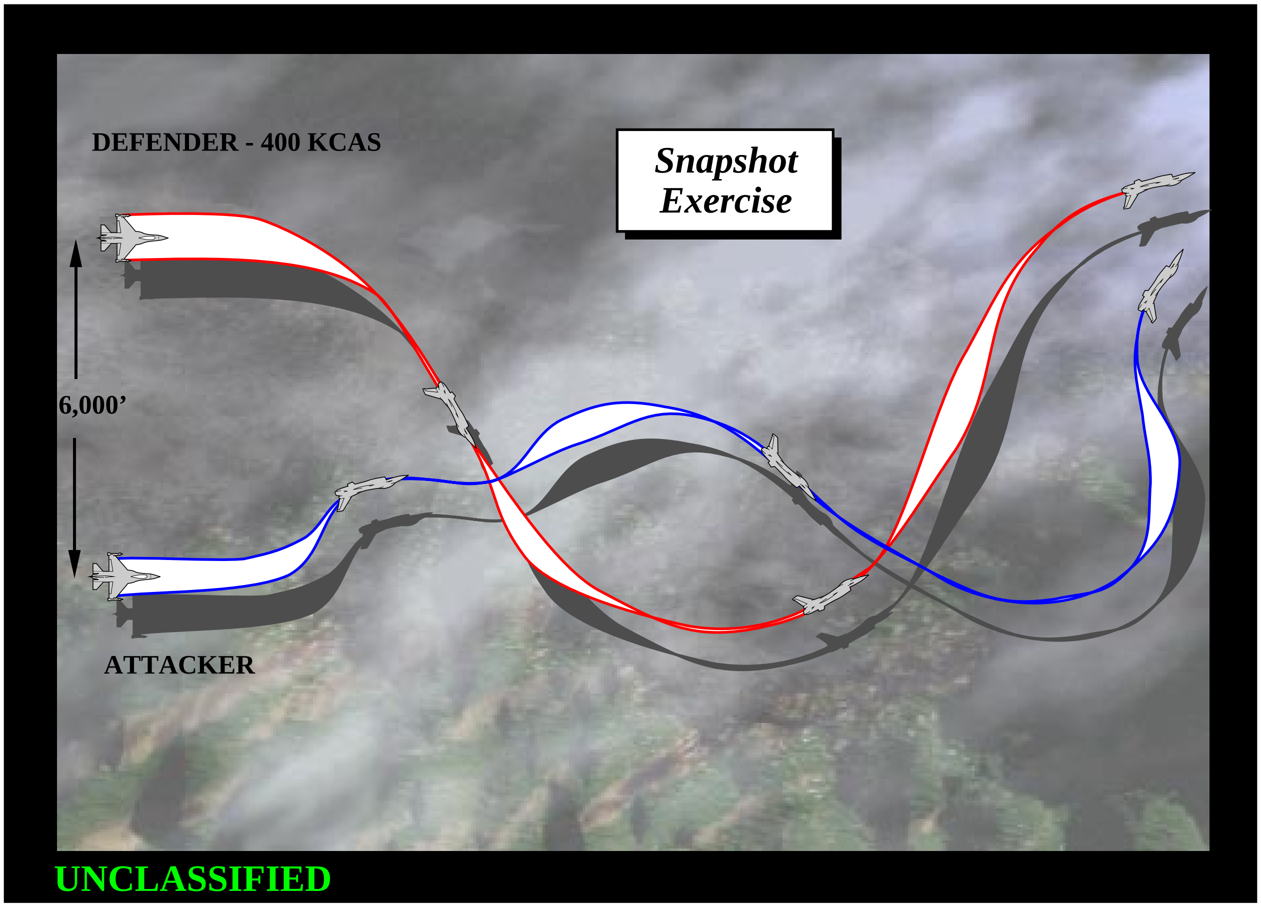
Figure 9.15. Roll-Slides Attacks.



NOTE: This exercise teaches the offender to establish required lead and establish correct plane and range to achieve gun parameters on a non-maneuvering target from a beam or front hemisphere start. One of the primary skills emphasized is to effectively employ the gun without violating training rules and minimum range. The offender should concentrate on using the gun cross to set weapons parameters and letting avionics and radar locks help to assess gunshots.

9.4.6. Snapshot Exercise. The offender starts at 6,000 feet line abreast with defender and airspeed approximately 400 KCAS (**Figure 9.16.**, Snapshot Exercise). At the "BEGIN MANEUVER" call, the defender starts a level turn into the attacker using G as necessary to create moderate (90 to 110 degrees) angle-off. The offender establishes lead and maneuvers for a quick gunshot, after which repositioning for another attack. Excessive G by the defender may result in heading crossing angle (HCA) greater than 135 degrees in which case the exercise will be terminated.

Figure 9.16. Snapshot Exercise.



NOTE: This exercise forces the offender to assess aspect angle, angle-off, and LOS rate to predict target motion and gun solution. It allows practice of the switchology required for quick gun attempts in a controlled environment.

CAUTION: Minimum-range bubble integrity must be maintained; if LOS stops, you are on a collision course and should immediately correct and terminate/KIO if required. The visual must be maintained at all times during the exercise to ensure safe practice.

9.4.7. Cross Turn Exercise. The exercise starts with a Line Abreast formation, wingman 5,000 to 7,000 feet out (**Figure 9.17.,** Cross Turn Exercise). The flight lead initiates the exercise by calling "CROSS TURN" and a MIL power, 3.0 to 3.5 G cross turn is performed. At approximately 120 degrees of turn lead calls "CLEARED TO MANEUVER." At the "CLEARED TO MANEUVER" call, the offender attempts to attain an entry to Fox II or guns parameters while the defender continues a 3-G turn. The attacker attempts to get the shot prior to the defender completing 360 degrees of turn. Terminate at the shot call. The offender basically has three avenues to arrive in weapons parameters:

- An immediate pitch to point and drive inside the defender's predictable turn circle, followed by a slice into weapons parameters (high-to-low entry);
- An immediate slice to point and drive inside the defender's turn circle, pitching up into weapons parameters (low-to-high entry);
- An unloaded extension for lateral turning room (approximately 3 seconds) followed by a pull-to-point at the defender in weapons parameters (belly entry).

NOTE: This exercise teaches the prediction of a bandit's turn circle and POM and recognition of sufficient turning room and lead required.

9.4.8. High-Aspect Gun Exercise. Start at 15,000 to 20,000 feet MSL, 400+ KCAS (**Figure 9.18.,** High-Aspect Gun Exercise). The offender should be 9,000 feet behind the defender, offset far enough to the side so the defender can maintain sight throughout the exercise. The defender initiates a 6-G, level, MIL power turn into the attacker. The defender pulls as required to place the attacker forward of 90 degrees of aspect. (The lift vector is 90 degrees of aspect. Placing the attacker in the HUD equates to 180 degrees of aspect.) The defender places the attacker between the lift vector and halfway to the HUD, resulting in 90 to 135 degrees of aspect. (Remember that 90 degrees of aspect is the most difficult shot, as it requires the greatest amount of lead angle, and has the highest LOS rate.) The offender remains in plane with the defender, and closes toward the defender for a high aspect shot. The defender plays the G as required to maintain 90 to 135 degrees of aspect. The attacker should be able to take the shot by 3,000 to 5,000 feet of range. Once the shot is taken, the attacker rolls wings-level and passes behind the defender. Both aircraft unload and extend away from each other. As both aircraft approach 9,000 feet of separation, they initiate a turn toward each other. The defender again pulls enough G's to place the attacker at 90 to 135 degrees of aspect. The attacker again closes for a high aspect shot. (The above sequence can normally be repeated three to four times before getting low on airspeed and altitude.) A High-Aspect Gun Exercise can also be accomplished with the same setup as an offensive heat-to-guns only with 6,000 feet line abreast and 400 KCAS starting parameters.

NOTE: This exercise offers the opportunity to practice using many of the enhanced envelope gunsight (EEGS) features to accomplish a high aspect gunshot. It also teaches recognition of higher aspect gun opportunities before transition into lower aspect gunshots.

Figure 9.17. Cross Turn Exercise.

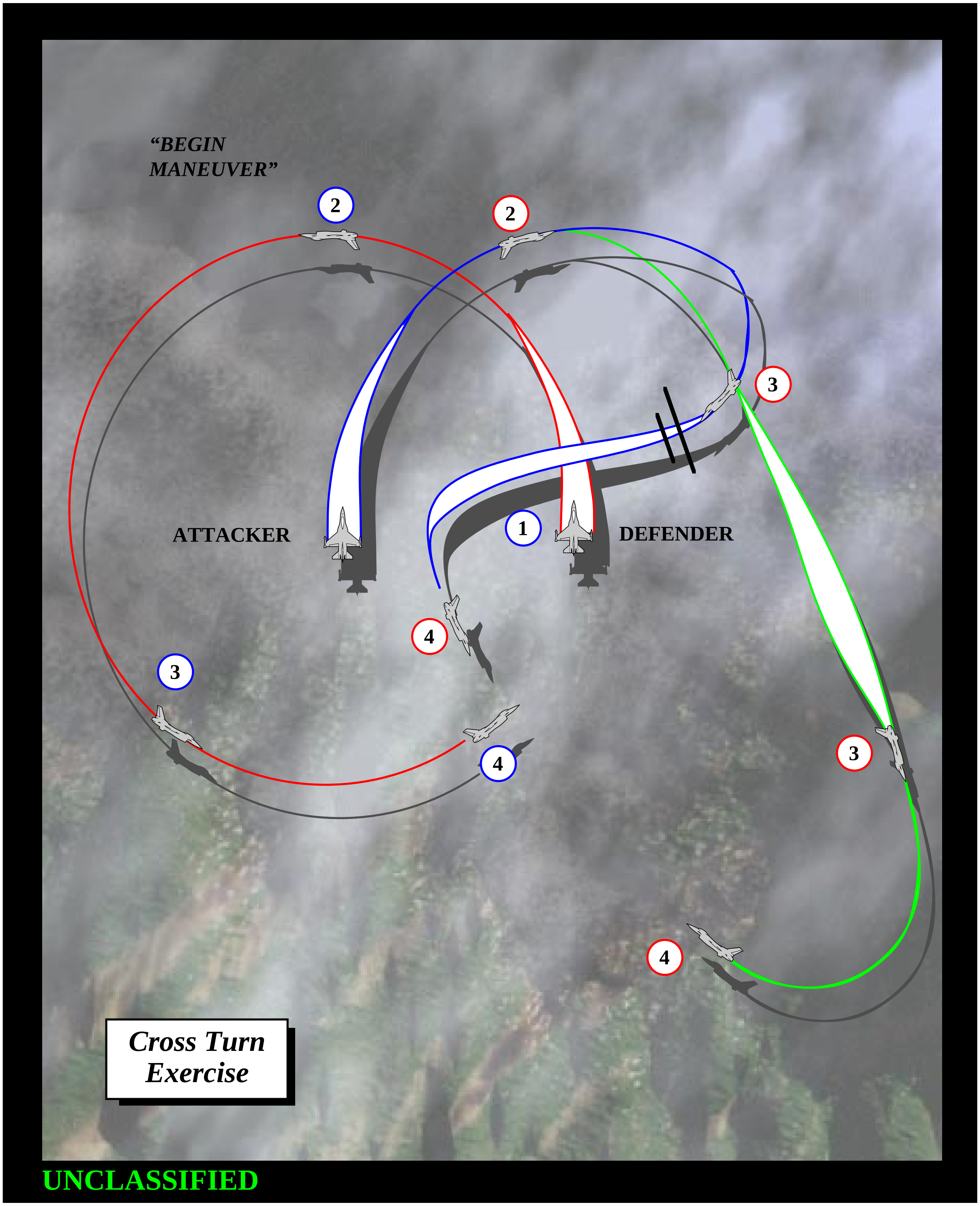
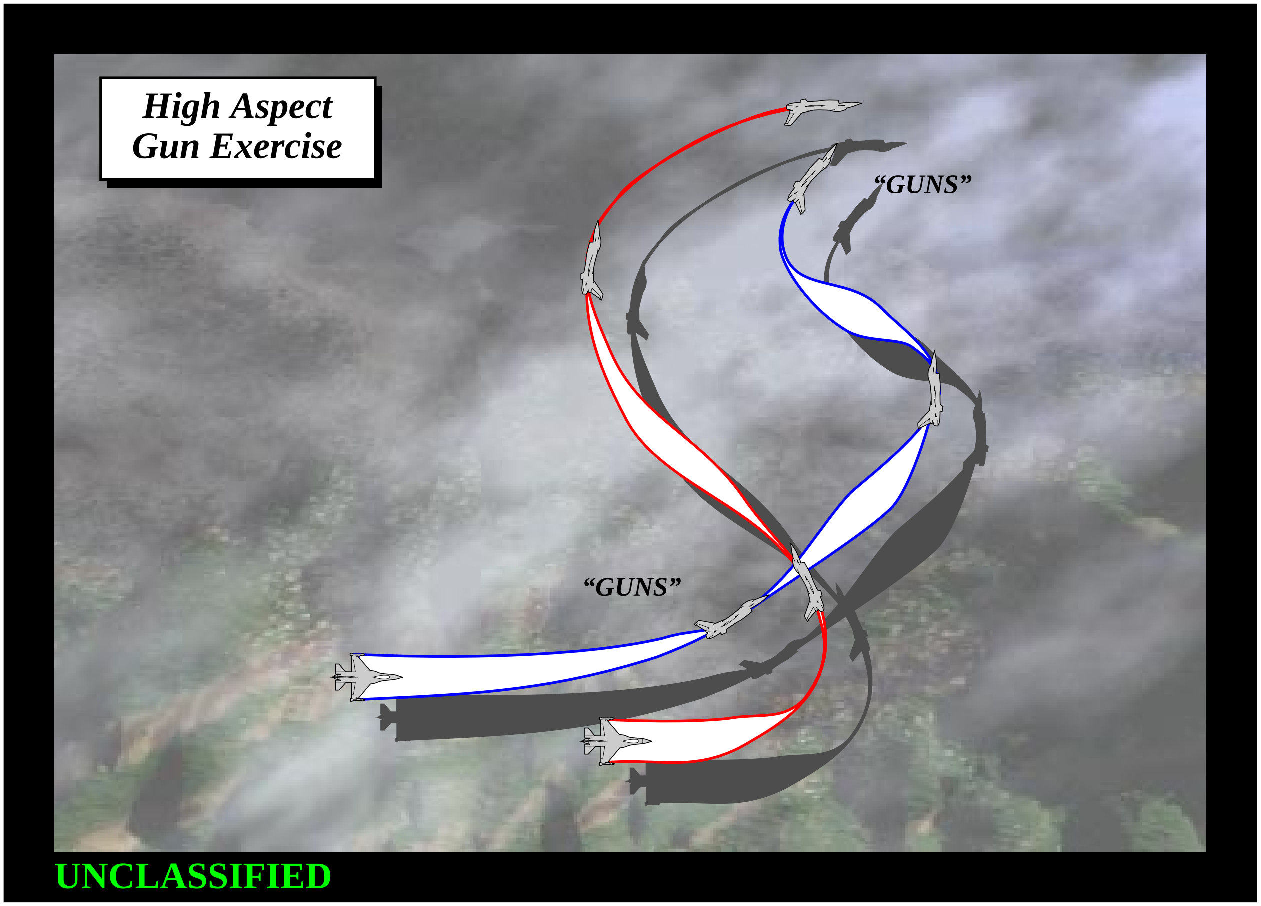


Figure 9.18. High-Aspect Gun Exercise.



9.5. Low-Altitude Training. This section includes a discussion of low-altitude hazard awareness and low-altitude step down training. Several types of maneuvers have been developed to acquaint the pilot with maneuvering in the low-altitude arena. Units will have a low-altitude step down training program consisting of both academics and flying. The following exercises are provided both for practice and optional low-altitude awareness training events. A description of the F-16 low-altitude warning is also provided.

9.5.1. Descent Awareness Training. This exercise shows the amount of altitude that may be lost in a short period of time due to inattention or channelized attention at low altitude. Beginning at 1,000 feet AGL or higher and 420 to 480 KCAS, establish a wings-level 1 degree nose-low descent. Time how long it takes to lose 100 feet, 300 feet, and 500 feet of altitude. Repeat the exercise with a 3-degree descent and again with a 5-degree descent. Do not descend below the minimum altitude established for the route/mission you are flying. Reference **Table 9.1.**, Time-to-Impact (Seconds) Wings-Level Descent, for examples.

9.5.2. Level Turn. This exercise gives the pilot practice at maintaining altitude while maneuvering in turns at various bank angles and G loading. Beginning at 500 feet AGL, 420 to 480 KCAS, establish bank angles between 30 and 90 degrees and set G to maintain level flight. Monitor the HUD FPM, altimeter, and visual cues to maintain level flight. Correct drops in altitude by first decreasing bank and then increasing G. With practice, the pilot should be able to perform a 360-degree level turn using 5 to 6 G's without varying altitude more than +100 feet and -50 feet. If authorized, repeat this exercise at 300 feet AGL. Reference **Table 9.2.**, Time-to-Impact (Seconds) in Overbanked Turns, for examples.

Table 9.1. Time-to-Impact (Seconds) Wings-Level Descent.

Dive Angle (Degrees)	Altitude (Feet) AGL	KTAS		
		400	450	500
1	700	59.5	52.9	47.6
	500	42.5	37.8	34.0
	300	26.1	23.2	20.9
3	700	14.2	12.6	11.4
	500	19.9	17.7	15.9
	300	8.5	7.6	6.8
5	700	11.9	10.6	9.5
	500	8.5	7.6	6.8
	300	5.1	4.5	4.1
10	700	6.0	5.3	4.8
	500	4.2	3.7	3.3
	300	2.6	2.3	2.0
UNCLASSIFIED				

Table 9.2. Time-to-Impact (Seconds) in Overbanked Turns.

Overbank (Degrees)	Altitude (Feet)	Bank/G Required for Level Flight Time (Seconds)		
		75 Degrees/4-G	79 Degrees/5-G	81 Degrees/6-G
5	500	12.0	9.8	8.5
	300	9.2	7.0	6.1
	100	4.3	3.8	3.3
10	500	7.0	6.2	5.4
	300	5.2	4.5	4.2
	100	3.0	2.6	2.4
15	500	5.5	5.0	4.5
	300	4.3	4.0	3.8
	100	2.2	2.0	1.9
UNCLASSIFIED				

9.5.3. CAT III Maneuvering. This exercise shows the airspeed and AOA effects of sustained maneuvering in a high drag/heavyweight configuration and is more pronounced when flown at gross weights of 30,000 pounds or greater. At 1,000 feet AGL or greater, perform a MIL power 180 degrees level turn using 5 to 6 G's, starting at 420 to 480 KCAS (note the airspeed loss and AOA increase during the turn). Do not slow below the low-altitude minimum airspeed. After performing the turn in MIL power, select AB and accelerate to 420 to 480 KCAS. With full AB selected, perform another 180-degree turn at 5 to 6 G's (note airspeed and AOA changes during this turn and compare them with the MIL power turn).

9.5.4. Turning Room Demonstration. This exercise enables the pilot to visualize the horizontal turning room required for the F-16 to complete a low-altitude turn at employment airspeeds. At 500 feet AGL or greater, 450 to 500 KCAS, fly perpendicular to a known ground reference line (road, railroad, power line, river, etc.). When approaching the reference line, perform a level 4- to 5-G turn using cockpit and outside visual references so as to roll out exactly over the reference line. Repeat this exercise until you no longer overshoot or undershoot the reference.

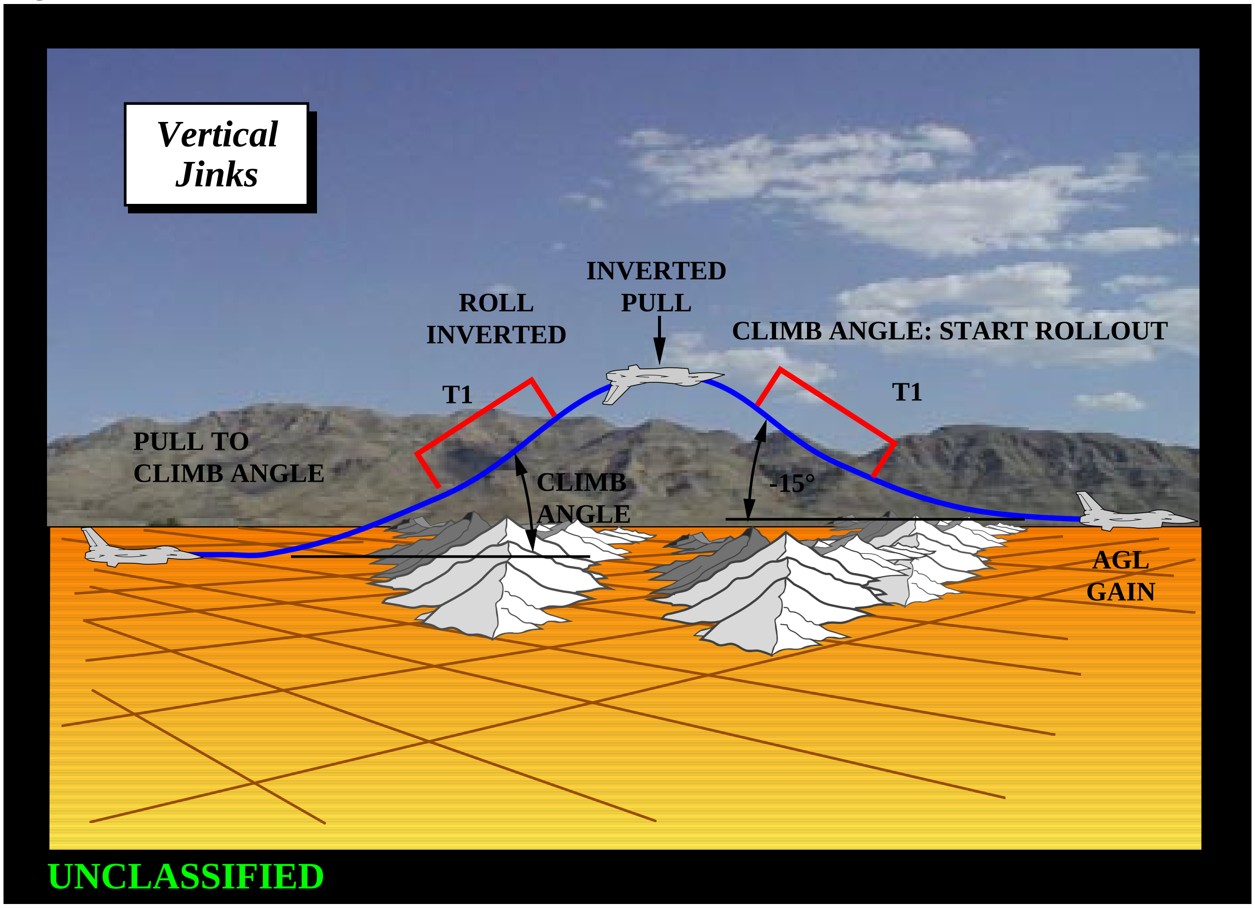
9.5.5. Vertical Jinks. Beginning at or above 400 KCAS, pull to a planned climb angle (not more than 30 degrees, delay 3 to 5 seconds) roll unloaded to inverted and pull through level flight to a dive angle 10 degrees less than the highest climb angle attained **(Figure 9.19.,** Vertical Jinks. Roll upright, hold the same delay as in the climb, and pull to straight and level. (***NOTE:*** Use the HUD pitch ladders to reliably determine dive angles. Use caution with high pitch rates because rapidly moving pitch lines are often difficult to read.) Accomplish multiple jinks up to 30 degrees and attain flight path angles within ±2 degrees and match all climb and dive delays within 1 second. This may also be accomplished in the oblique with a planned offset turn/bank. Minimum recovery altitude is 1,000 feet AGL.

9.5.6. Reversals. Begin at planned altitude, level flight, and 400 KCAS minimum. The flight lead calls "(CALLSIGN), LEFT/RIGHT TURN," check turns, comeback calls, etc., to initiate level turns. Each pilot should concentrate on flying the directed maneuvers while usually monitoring the other aircraft. Emphasis must be placed on awareness of overbank and subsequent descent potential. Roll rates will be smooth and controlled with bank angle stabilized momentarily at 45 and 60 degrees before proceeding to 3 to 4 G's.

9.5.7. Acceleration and Deceleration. Starting at 350 KCAS, accelerate in AB to 500 KCAS at 500 feet/300 feet AGL. Maintain altitude while decelerating with speed brakes and then idle power until 300 KCAS. Select MIL power, close speed brakes, and accelerate while maintaining altitude.

9.5.8. Visual Lookout Exercise. This is designed to train pilots to visually clear the 6 o'clock area while maintaining a low-altitude profile. From straight and level flight at or above 500 feet AGL and 400 KCAS, keep track of flight lead position as he maneuvers in a 45-degree cone 2,000 feet to 2 NM behind, from level to 4,000 feet high on the trainee. Strong emphasis must be placed on altitude, terrain changes, trim, stick pressure when looking aft, and task prioritization while checking six. The pilot must remain within ±50 KCAS with no descent rate. The pilot should also be able to visually keep track of flight lead position and estimate range within 1,000 feet. Do not sacrifice aircraft control to maintain the tally!

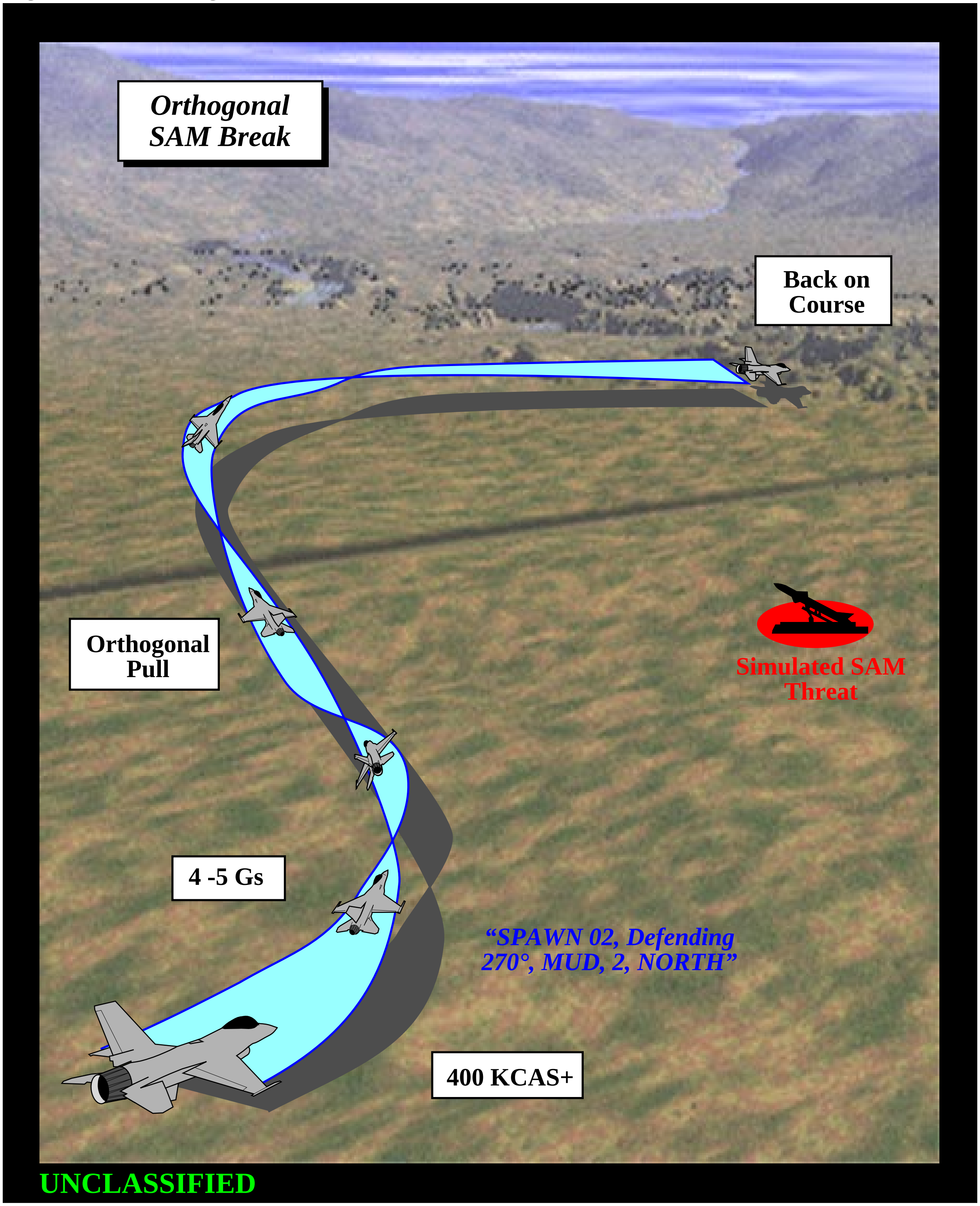
Figure 9.19. Vertical Jinks.



9.5.9. "S" Turns. This is a series of banked turns linked by unloaded reversals as defensive reactions to ground threats. Establish level flight and 400 KCAS minimum, roll to 60 to 70 degrees of bank and make a level turn away from the threat. Continue the turn for 90 degrees, perform an unloaded reversal to 60 to 70 degrees of bank and continue turn for another 90 degrees of turn. Perform an unloaded reversal and turn to the original heading. Altitude control should be within +100 feet/-25 feet of starting altitude.

9.5.10. Orthogonal SAM Break. From straight and level flight, 400 KCAS minimum, initiate a level hard turn to place the simulated threat at 3 or 9 o'clock **(Figure 9.20.,** Orthogonal SAM Break). Simulating threat acquisition, start a hard out-of-plane pull perpendicular to the intercept axis of the threat. The perpendicular pull resembles part of a barrel roll as you continue to pull and roll to keep the threat at 3 or 9 o'clock until threat overshoot. At low altitude, once the nose approaches the horizon or the aircraft attains 120 degrees of bank, stop the maneuver and perform a recovery. Minimum altitude for recovery is 500 feet AGL. Terminate if minimum low altitude airspeed is reached.

Figure 9.20. Orthogonal SAM Break.



9.6. Flame-Out Approach Techniques and Procedures. A flame-out (FO) approach may be anything from a 360-degree overhead to a straight-in approach. It is entirely a function of available potential energy versus distance, with certain modifiers such as the nature of the emergency, weather, airfield conditions, etc. The overriding consideration, of course, is the safe recovery of “the world's hottest fighter pilot,” with “the world's most capable and awe-inspiring fighter” a distant second. It is, therefore, extremely important to recognize when recovery of the aircraft is no longer feasible so that safe recovery of the pilot can be employed as early as possible to increase the odds for survival. Do not commit to a dubious or unsafe approach under any circumstances. When in doubt, jump out. The good news is that it is relatively easy to determine whether you are within valid FO parameters as long as certain basic criteria are met.

NOTE: A flamed-out F-16 has the capacity to cover a finite distance over the ground based on altitude, aircraft configuration (weight and drag), winds, and field elevation. Assuming that the best glide speed for the aircraft configuration is maintained, the only significant variable to be accommodated is the wind. Since the FPM (if available) takes winds into account and the best glide speed for the configuration generates an optimum glide slope, it is then only necessary to determine where the recovery field is relative to the FPM to determine if the approach will be successful. If the field lies beyond the FPM, the approach will be short and ejection should be considered. If the field lies short of the FPM, excess energy is indicated which may accommodate a variety of successful approaches and landings. The overhead approach affords the most opportunities to properly manage available energy while providing the best visual clues for pattern corrections. With reference to the HUD, however, the straight-in approach can also be a viable alternative. Some blocks of the F-16 lose the HUD when the EPU is activated. This will require HUD-out approach and landings when the EPU is on (i.e., engine failure). Practice simulated FO approaches without the HUD FPM or with the HUD off to the maximum extent possible in these aircraft. Know your jet!

9.6.1. Straight-In Flame-Out Pattern and Approach. In the Dash 1 is a discussion of a straight-in SFO. Maintain an optimum speed gear-up glide until the initial aimpoint on the runway is 11 to 17 degrees below the horizon, then lower the gear and continue the glide at optimum gear-down speed. Engine-out tests at Edwards AFB resulted in a gear-down best range glide between 10 and 11 degrees flight path angle which could be steepened to 17 degrees flight path angle with the speed brakes; thus the 11 to 17 degrees window for lowering the gear. The Dash 1 does not include HUD techniques for the FO, nor does it discuss the effect that a headwind or tailwind will have on the 11 to 17 degrees flight path angle window. Experience has shown that energy can be managed most effectively with reference to the HUD FPM and pitch lines *while maintaining optimum airspeed*. Pilots should still be ready to accomplish a FO without a FPM. At optimum airspeed (gear up) the aircraft is approximately 6 to 7 degrees AOA and the 11- to 17-degree flight path angle occurs as the approach end of the landing runway disappears beneath the nose of the aircraft.

9.6.1.1. The FPM Accounts for Wind. For every 20 knots of headwind component, the FPM will show about a 1-degree increase in flight path angle (aircraft pitch/AOA to maintain optimum airspeed does not change). Establish and maintain optimum airspeed for the configuration. When all variables are accounted for, the HUD will accurately depict the optimum flight path. Regardless of actual flight path angles involved, lowering the gear will increase the flight path angle 3.5 to 4 degrees. When the engine quits, jettison stores and turn toward the nearest suitable runway. Establish best range speed of 210 KCAS (plus fuel/stores) (***NOTE:*** Trade excess airspeed for altitude.) The EPU should be on (if the engine is windmilling with aircraft fuel available) the jet fuel starter (JFS) should be turned on below 20,000 feet MSL to extend EPU operating time (10 minutes with normal demands; up to 15 minutes with the JFS running). The JFS will also provide B-system hydraulic pressure for normal gear extension, normal brakes and nosewheel steering. With an optimum glide established, if the FPM is on the runway or beyond and optimum speed is maintained, the threshold will slowly move downward in the HUD field of view (FOV) indicating excess energy (in terms of altitude) for the approach. This is good because sooner or later the initial aimpoint (one-third of the way down the runway) will lie within the gear-down window. The gear may be extended when the aimpoint is between 11 and 17 degrees and landing is assured.

9.6.1.2. EPU Fuel Depletion. If EPU fuel depletion is a factor because of range to the runway, consider a 10-degree gear-up glide when the best range glide given is a 1:1 ratio between altitude in thousands of feet and range to the runway (i.e., 20,000 feet AGL at 20 NM). Airspeed can be increased to 300 to 330 knots, cutting time required to reach the runway and reducing EPU fuel used (see Dash 1, *FO Procedures* for more detailed information). When the gear is lowered (alternate extension required unless the JFS is motoring the engine), continue the glide at best range (gear down) speed. Use speed brakes as required to maintain the desired glide path and airspeed parameters, and achieve a steady-state optimum gear-down glide prior to the flare point with the FPM on the aimpoint. In a nutshell, if the aircraft flames out, regardless of altitude or distance out (within EPU fuel constraints), and the recovery field is below the 7-degree pitch line, you immediately know you can get there. Winds can affect this equation.

9.6.1.3. Maintain Optimum Speeds Throughout Approach. Unless you confirm an energy surplus, it is extremely important to maintain optimum speeds throughout the approach. Excessive airspeed will increase the glide path angle and consequently decrease range. Low airspeed will do the same thing, in addition to providing progressively less energy to flare the aircraft or zoom to safe ejection parameters. Below the gear down minimum speed, the FPM shifts dramatically towards you (short), and energy may be insufficient to flare and touch down without damaging the aircraft, or worse. There is no way to “stretch” the glide. If the aimpoint shifts upward in the HUD FOV beyond the FPM, this indicates that you will not be able to make the runway. Ejection should not be delayed in a futile attempt to salvage a questionable approach.

9.6.1.4. Touchdown. If you have managed your energy to achieve an optimum gear-down glide with the FPM on the initial aimpoint, the only chore remaining is to flare and land the aircraft on touchdown between 10 and 13 degrees AOA with enough runway remaining to stop the aircraft before running out of runway or cables. Once landing is assured, the recommended procedure is to shift the aimpoint from one-third down the runway to a position short of the intended touchdown point. Techniques presented here will consistently produce touchdowns at 2,500 feet to 3,000 feet. If a shorter touchdown is required, simply adjust the optimum glide aimpoint an appropriate distance short of the threshold. The trick is to transition from a “steep final” to a touchdown flight path angle of less than 2 degrees. If the flare is too abrupt or begun too early, the aircraft will run out of airspeed prior to touchdown. The result is an excessive sink rate and probable damage to the aircraft. The opposite is also true—the aircraft cannot hit the runway in a 10-degree dive and expect good results.

9.6.1.5. SFO Practice. With practice, a SFO flare will become second nature. Meanwhile, there is an easily remembered set of parameters which will approximate what you are looking for and help to avoid the extremes as discussed in **paragraph 9.6.1,** Straight-In Flame-Out Pattern and Approach. At about 300 feet AGL, start a smooth flare. This will give you a picture similar to a normal final and get you into ground effect with enough energy to complete the flare (hold it off if necessary) and grease it on at 10 to 13 degrees AOA. The speed brakes should normally be closed at this point. Use them if needed but realize they will dramatically increase energy decay if extended during normal roundout and flare.

9.6.1.6. Energy State. If the energy state (glide slope/altitude with respect to the runway) is too great to be managed with speed brakes alone, dive off altitude or modify the ground track. Use caution when employing either of these methods. It is very easy to overdo the correction since either method may involve removing the runway environment from the HUD FOV during the correction. The overhead approach may be entered at any position provided the proper altitude for that point in the pattern can be obtained. The main concern is to reach high key, low key, or base key at or above prescribed minimum altitudes.

9.6.2. Overhead Flame-Out Pattern Approach. For an overhead approach, plan to arrive at an appropriate high key altitude based upon aircraft gross weight. At high key in the landing configuration, turn to downwind/low key at approximately 60 degrees of bank and constant airspeed, optimizing the F-16's turning capability and minimizing altitude loss. By using a 60-degree bank turn, more time is spent wings-level and energy state is assessed more easily. If off conditions at high key, adjust the pattern as necessary (delay landing gear if low, extend down the runway if high) to achieve low key parameters. Delaying landing gear until low key will decrease altitude loss by 1,000 to 1,500 feet. If on conditions, continue downwind until the touchdown point is 10 to 45 degrees aft of abeam, depending on wind. Fly the final turn at optimum airspeed (9 to 11 degrees AOA) and, after rolling out on final, maintain airspeed with nose-low, setting the FPM short of the runway threshold until pre-flare. Use speed brakes as required on final to control airspeed. The ground track of the overhead approach is approximately the same as that of a normal overhead landing approach except the final approach will only be 0.5 NM long. Expect the aircraft to float 3,000 to 4,000 feet horizontally before touchdown at 10 to 13 degrees optimum.

9.6.2.1. After meeting low key parameters, you will usually be high and steep on final unless you adjust in the base turn. If this is the case, use pitch and speed brakes as required to arrive at the round-out point with a 10-degree flight path angle. In the absence of a positively recognized energy advantage, maintain an optimum airspeed until it is ascertained that the 10-degree aimpoint is on the threshold or close enough to it to place the touchdown point on the runway surface. If it is not, it is time to eject. Do not pull the FPM up to the runway in an effort to lengthen the aimpoint. The resultant loss of airspeed may preclude a successful round-out and flare. When at approximately 300 feet AGL, employ the same flare technique for the straight-in approach.

CHAPTER 10

LOW-ALTITUDE NAVIGATION AND TARGETING FOR NIGHT

10.1. The LANTIRN System. The low-altitude navigation and targeting infrared for night (LANTIRN) system is a self-contained dual-pod system that provides specified F-16 units with a day/night/under-the-weather, low-level navigation, and precision air-to-surface weapons delivery capability. The terrain-following radar (TFR) provides ground clearances for limited weather penetration capability during ingress and egress. F-16 LANTIRN aircraft can be employed across the entire mission spectrum. The primary focus of this chapter is night, medium altitude, laser guided bomb (LGB) employment. The major areas covered are general LANTIRN mission planning considerations, night LANTIRN ground operations, cruise/en route sensor optimization, and LANTRIN attack planning considerations. Low-altitude LANTIRN considerations are addressed at the end of this chapter. Refer to AEM, Volume 5, the Dash 34 series, and appropriate Air Force instructions for further guidance.

10.2. LANTIRN Mission Planning Considerations. A discussion of the general factors to be considered during the mission planning process is contained in **Chapter 5**. This section will discuss the mission planning considerations specific to F-16 LANTIRN missions.

10.2.1. LANTIRN Operations. LANTIRN operations consist of both the navigation pod (NVP) and targeting pod (TGP) unless specifically noted. While non-TFR operations can be conducted at or above the minimum safe altitude (MSA), the use of the TGP at night is restricted to use above 5,000 feet AGL for Category I pilots. During daytime operations, there is no altitude restriction for TGP use. Refer to appropriate instructions for TGP restrictions for Category II and III qualifications.

10.2.2. Mission Preparation. Special planning considerations are driven primarily by the physics of the infrared (IR), vice the visual light spectrum, and the limited field of view (FOV) of the LANTIRN system compared to the human eye. IR imagery is fully discussed in MPM 3-1, Volume 1.

10.2.3. FOV Limitations. The NVP FOV (28 degrees horizontal x 21 degrees vertical) is adequate for navigation and target attack if the aircraft is positioned to center this FOV on turnpoints, IPs, and targets. The probability of successfully identifying a point drops off significantly if the point falls outside of the HUD FOV. To have a high probability of success, the system point of interest (SPI) (driven by inertial navigation system (INS), global positioning system (GPS), or sensor cueing) must be accurate within 0.2 to 0.3 NM. In the absence of GPS, frequent INS updates and altitude calibration (ACAL) are necessary to maintain system accuracy. In most cases, the TGP adequately compensates for this limitation in the NVP FOV.

10.2.4. Turnpoint Selection. In most cases, good visual turnpoints make good forward looking infrared (FLIR) turnpoints. The two ingredients of valid FLIR turnpoints are IR contrast and vertical development. It is best to have both, but as a rule, IR contrast is the most important. Accuracy of coordinates is critical in mission planning. Ideally, the pilot would have high confidence in the coordinate accuracy of each point on the route, so that if the INS started drifting, the pilot could update the system solution at any time. Because of the time it takes to derive mensurated coordinates using systems like the Analytical Photogrammetric Positioning System (APPS), this will require a substantial amount of pre-planning by units in their expected area of employment if they are to be responsive to short-notice tasking. The integration of Falcon View into current mission planning software, as well as systems such as Dew Drop, allows planners to easily achieve the desired level of accuracy for steerpoint data. While not technically mensurated, these systems can achieve accuracy to within 5 meters or less.

10.2.4.1. As a general rule, try to ensure that a readily identifiable LANTIRN turnpoint is along the ingress route every 10 minutes of flight. A precise update is then available if the system is off by more than 0.1 to 0.3 NM. GPS, especially at lower altitude, is mission critical. Without it, pilot work load is greatly increased. Ensure that a radar significant turnpoint or offset aimpoint (OAP) is available somewhere along the route (where cockpit tasking is low) and at the IP (for a "last chance" update, prior to weapons employment). This provides an acceptable opportunity to verify and correct the navigation solution if the TGP is inoperative or the steerpoint is obscured by weather.

10.2.4.2. LANTIRN missions require extensive use of the slew controller in the A/G mode. The reliance on radar significant turnpoints, use of the snap look function of the NVP FLIR, and TGP slewing have the potential to corrupt the cursor deltas. Therefore, with a high system accuracy (HIGH/HIGH), it is important to cursor zero (CZ) often. In most cases, with a HIGH/HIGH, it is advisable not to input any slews into the system if the turnpoint can be identified in the FOV of the sensor. If slews are input and a high system accuracy can be verified, the habit pattern of TMS AFT, CZ, WIDE FOV should be continued along the route to subsequent steerpoints.

10.2.4.3. Given system accuracy without GPS (0.8 NM per hour specification), the INS will require updates approximately every 15 minutes. Additionally, the accuracy of the system altitude will affect weapons delivery calculations and TGP vertical pointing angles. Both the system altitude and the INS present position should be kept as accurate as possible, however, only perform actual "fixes" if system inaccuracy can be verified.

10.2.5. Weather Support. To help interpret the IR scene, LANTIRN pilots require IR information, such as absolute humidity, Delta T values, etc, in addition to conventional weather data. The weather service has developed a tactical decision aid (TDA) to provide this support.

10.2.5.1. To compute a TDA, the weather forecaster must know the target location and description, time over target (TOT), acquisition and weapon release altitude, expected attack axis, and the background characteristics of the target. This information is provided by the pilot or by intelligence personnel. During contingency operations, a planning forecast of IR conditions within given geographical areas during specific time periods will be available to assist wing and squadron mission planners. This forecast would include expected acquisition and lock-on ranges, thermal contrast, and the polarity of previously agreed upon targets.

10.2.5.2. TDA information should include:

- Maximum TGP/AGM-65D/G acquisition range at given altitude.

- Maximum TGP/AGM-65D/G lock-on range at give altitude.
- Maximum laser designation and detection range.
- Maximum LGB seeker detection range.
- IR polarity (target hotter or colder than background) at acquisition/lock-on.
- Apparent thermal contrast (degree to which the target is distinguishable from background) at acquisition range.
- Optimum attack axis for maximum range acquisition and lock-on.

10.2.6. Environmental Considerations.

10.2.6.1. Weather. Weather has a great affect on the IR scene, as well as IR seeker performance. Clear skies, precipitation, clouds, wind, and previous weather affect FLIR detection ranges and laser performance.

10.2.6.2. Clear Skies. At night, rapid radiation cooling increases thermal contrast. Targets and backgrounds with low thermal inertia cool rapidly at night. Those with high thermal inertia retain much of the heat gained during the day.

10.2.6.3. Precipitation. Water vapor in the form of rain, snow, clouds, and fog, absorbs IR radiation and scatters thermal energy, thereby reducing acquisition range. Rain and snow reduce the transmission of IR energy and decrease apparent Delta T. Delta T gradually decreases as precipitation continues to fall. Falling precipitation restricts IR detection more severely than that which has already fallen. Solar and friction heated target features suffer the most heat loss. Friction heat loss is caused by water and mud accumulating on tracks and wheels. Heated areas stand out more clearly against cool and washed-out backgrounds. Rain affects horizontal surfaces more than vertical surfaces. Rain effects are magnified by the types of material in the target area. Porous materials soak up water and take longer to dry than nonporous materials. At low viewing angles, snow reflects the sky temperature and appears cold on the display. Under clouded skies, at lower altitudes, snow reflects warm clouds, which emit absorbed solar radiation. Snow appears warm under this condition. Previous weather can have a tremendous impact on thermal contrast and must be considered in mission planning. A recent rain or snow shower can wash out the thermal contrast of the target and background.

10.2.6.4. Clouds. Clouds directly affect LANTIRN operations since they can block IR energy. Cloud free line of sight (LOS) is required to see the target. When using the TGP, LOS must be maintained or the TGP will either break lock or transfer lock to a cloud. An overcast can also greatly effect the IR visibility beneath it by reducing temperature contrasts.

10.2.6.5. Wind. Wind reduces the Delta T between the target and background. The higher the wind speed, the less the Delta T. Targets and backgrounds with low thermal inertia are more sensitive to wind than those with high thermal inertia. The greatest change in temperature occurs when wind speed increases from 0 to 5 knots. Wind also affects LGB delivery and trajectory during the terminal phase. For detailed information on wind effects on the LGB reference AEM 3-1, Volume 5.

10.2.7. Mission Materials. Cockpit management is a critical part of flying the LANTIRN mission. Pilots must be very familiar with their planned route prior to flying a night LANTIRN mission. Reduced copy mission materials are difficult to read at night and require additional heads down time. Ensure all copies of mission products are legible and minimize the number of mission products to only those required to accomplish the mission. The following mission materials are considered to be mission critical: Mission data card, route map, attack profile, and target photographs (one big-to-small and one close-up of the desired munitions point of impact [DMPI]).

10.2.8. Targeting. With the LANTIRN system, plan missions against targets that are geographically and IR significant. LANTIRN depends on thermal contrast between the target and background, as opposed to visual contrast, for target acquisition. In general, a high Delta T (defined as the target IR signature is significantly different than that of its background and shows up clearly in an IR sensor) target can be acquired at longer ranges and with more ease than a target with a low Delta T. The probability of mission success is reduced when choosing a standoff delivery against a target with both low transmissivity and Delta T. Weapons used during day operations are equally effective for night operations; however, FLIR limitations and their impact on accuracy (resolution, boresight errors, etc.) must be considered when choosing a munition. PGMs should be considered a higher priority than general purpose (GP) bombs for the LANTIRN mission when the TGP is available.

10.3. Ground Operations. The night LANTIRN preflight presents some interesting challenges. Due to the requirement to use a flashlight and spend more time looking at each pre-flight item, it is a slower process. Preflight of the TGP should ensure that the laser is set to either COMBAT or TRAINING, as required. With actual LGBs, ensure the laser code is properly set on both the guidance kit on the bomb and in the upfront controls (UFC). Check the left and right hardpoint correction coefficients in the aircraft forms and verify the correct data is input in the general avionics computer (GAC).

10.3.1. After Start. Ground operations and checklist procedures are essentially the same as daytime operations. After the secondary engine control (SEC) and emergency power unit (EPU) checks, turn on all avionics and sensor power. Once the left hardpoint is powered on, select STBY on the FLIR multifunction display (MFD) page to begin the time-in process. Reduce lighting as much as practical as the eyes start to adjust to the night lighting. However, cockpit lighting during a LANTIRN mission will still be considerable due to the bright video displays of the FLIR, TGP, and MAVERICK. The key is take the time to set the desired brightness during ground operations to prevent distraction from a bright MFD once airborne.

10.3.2. Function Checks and Setup. Function checks verify initial sensor operation. Function checks include sensor built-in test (BIT) checks and sensor operation checks.

10.3.2.1. BIT Checks. During the time-in process, all sensors perform a start-up BIT (**Table 10.1.,** BIT Checks). Additionally, pilot initiated BIT checks should be performed to enhance the start-up BIT. The FLIR and TGP should be BIT checked on every night sortie, and the radar altimeter (RALT) and TFR should be BIT checked if planning to fly low altitude using the TFR. BITs can be accomplished as soon as the “not timed out” messages are out of the MFD displays.

Table 10.1. BIT Checks.

Display	Time	Description
FLIR	15 to 30 seconds	After FLIR BIT selection on the TEST page, go back to the FLIR page to ensure the BIT takes place. This can be verified by BIT in place of STBY in the upper left-hand of the MFD. During the FLIR BIT you will see an IR picture and then the MFD will flash.
TGP	80 seconds	Prior to initiating the BIT, unstow the TGP. Ensure the laser is armed in order to verify proper laser function. At completion of the BIT, stow the TGP and safe the laser. NOTE: The laser will only fire in the training mode during the BIT check regardless of the actual setting on the TGP itself.
RALT	3 to 5 seconds	The display on the test page will go from 0 to 300. When the RALT de-highlights, the BIT is complete.
TFR	1 minute	Like the FLIR BIT, after BIT selection go to the TFR page and confirm BIT in the upper left-hand of the MFD.
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10.3.2.2. Sensor Operation Check/Setup. See **Table 10.2.**, Sensor Operation Check, for detailed information.

10.3.2.3. Systems Setup. After tuning and boresighting the various pods and systems, ensure all systems are appropriately set up for the mission. Do not forget to set the desired laser code and laser start time (LST) in the UFC. MFD setup is an important habit pattern to develop. The primary logic in setting up the MFDs is to keep MFD pages in the same position as much as possible. The following medium-altitude MFD setup optimizes standard setup and allows hands-on operation during time-critical periods. This technique is geared toward LGB employment, but also lends itself to MAVERICK employment (**Table 10.3.**, MFD Setup).

Table 10.2. Sensor Operation Check/Setup.

Display	Description
FLIR	The FLIR must be checked for proper operation prior to flight. The BIT checks the actual NVP FLIR itself, but it's operation must be verified in both the MFD and the HUD. Ensure FLIR video is present in both the MFD and the HUD. Accomplish initial FLIR tuning IAW the Dash 34. Once initial tuning is complete, set the FLIR polarity as desired. In most cases, it is advisable to set the polarity to white hot (WHOT) to view hot objects as white. This will assist in achieving a FLIR boresight, since most objects at night that are visible with the naked eye tend to be heated objects (lights, the tower, another aircraft's exhaust plume, etc.). It also matches most IR MAVERICK displays. Once airborne, adjust the brightness and contrast for comfort and terrain resolution. Adjust the Level and Gain as required to fine-tune the FLIR. In most cases, running with the FLIR in AUTO provides sufficient Gain and Level to accomplish the mission. In higher humidity environments and for continuously computed impact point (CCIP) deliveries at night, it is important to achieve the best Gain/Level adjustment to ensure target features are identifiable in the FLIR image.
FLIR BSGT	Accomplish IAW the Dash 34. Often, the FLIR can be boresighted on the ground, if sufficient visual references are available to compare with the FLIR image. Parallax errors for images close to the F-16 tend to decrease the effectiveness of the ground boresight (only in the horizontal axis). As a general rule of thumb, for objects greater than 6,000 feet, a ground boresight provides sufficient accuracy to transition to in-flight FLIR use. The most accurate FLIR boresight is an airborne boresight. An airborne boresight is accomplished by selecting BSGT on the FLIR MFD page and slewing the hot spot of the preceding aircraft so it is just slightly below the tail light (with the aircraft centered in the HUD while in straight and level flight). Select the boresight function with the symbology in the area of the HUD where the expected bombing solution occurs. A boresight can also be accomplished on objects on the ground, however, sufficient visual references must be available to ensure an accurate boresight.
TGP	TGP operation can be verified by entering the A/G master mode and selecting DTOS. Verify the TGP slaves to the DTOS container and the SOI changes to TGP when you DMS AFT. Once the sensor of interest (SOI) is in the TGP, verify proper operation of the polarity and FOV functions. In many cases, operating the TGP in AUTO will provide sufficient scene detail to identify turnpoints and the target. However, since the quality of the any FLIR image is very much a function of absolute humidity, the FLIR image can be improved by manually adjusting the Gain (and sometimes Level), as well as adjusting the brightness and contrast. Once airborne, select a steerpoint to optimize the TGP FLIR image. Focusing the TGP on the ground is not recommended. Accomplish a TGP focus while airborne.
MAV BSGT	The MAVERICK boresight is exactly the same as daytime operations. At night, however, sufficient visual references must be available to ensure the TD container in the HUD matches the IR image in the MAVERICK. Point track the TGP on an object to verify missile boresight correlation operation. If required, change the SOI to the MAV and manually slew and track the same object prior to pressing the BSGT OSB on the WPN page. Verify operation/boresight of both missiles, if applicable. Prior to turning MAV power OFF, set the desired polarity (HOC/COH/AREA) and FOV. MAV must be timed in and the Ground Jettison switch must be in ENABLE to view MAVERICK video prior to accomplishing a boresight.

Table 10.3. MFD Setup.

MASTER MODE	LEFT MFD			RIGHT MFD	
NAV	FCR*	FLIR	TEST	SMS	TGP*
A/G (LGB)	FCR	—	SMS*	—	TGP*
A/G (AGM-65)	FCR	WPN*	SMS	—	TGP*
A/A	FCR*	—	—	SMS	TGP*
* Displayed front page of the MFD (i.e., page showing on MFD).					
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10.3.2.4. Consistency and Sensor of Interest (SOI) Management. The reasoning behind this setup is to always have the TGP in the same spot all the time (habit patterns). In addition, this allows the brightness and contrast of MFD pages to be optimized for each specific sensor. Also, minimizing the number of actual pages on the MFDs reduces the possibility of self-induced SOI errors and the requirement to DMS left/right. For A/G operations, with stores management system (SMS) moved to the left MFD, the SOI automatically initializes to the TGP (primary cueing sensor), as long as SMS is the displayed page on the left MFD. This also allows hands-on SMS corrections without having to take your hand off the stick. When the ground map (GM) radar is desired, DMS left, then transfer the SOI to the radar (DMS AFT). For AGM-65D/G operations, WPN on the left MFD also allows the pilot to view both sensors (TGP and MAV) simultaneously and affords the capability to monitor missile boresight correlation. Since the FLIR is usually displayed in the HUD, there is no reason for the FLIR to be on any MFD, other than when in the NAV Mode (same philosophy for the TEST page). For A/A operations, once the SMS is set-up appropriately, there is no requirement for the SMS to be displayed. Any A/A SMS change requirements are usually indicated visually in the head-up display (HUD) (i.e., wrong missile is selected).

- Delete WPN from A/G if a MAVERICK is not carried.
- In NAV and A/G master modes, use the A/G mode of the TGP. In A/A modes use the A/A TGP mode.
- Administrative MFD pages such as data transfer equipment (DTE), TEST, and flight control system (FLCS) can be placed in open slots at pilot preference. However, it is recommended that they not be located in either A/A or A/G master modes where they may force an extra DMS left or right to get to a more important MFD page.
- The specific order on each MFD is not as important as priority. Ensure that one DMS left or right moves from the primary option on that MFD to the secondary option. Obviously if there are only two options on the MFD, there is not a problem.
- For low-altitude TFR operations, put the TFR MFD page where it can be monitored to the maximum extent possible.

10.4. En Route Considerations. En route tasks are no less important for a night mission than for day. All the same day considerations apply during the night, however they are complicated by an inability to "look outside the cockpit" and the lack of true visual mutual support. The en route tasks fall under three general categories: Navigation, marshaling/holding, and ingress/egress.

10.4.1. Navigation. Navigation is more difficult at night and requires a greater dependence on an accurate system solution. Additionally, night formation contracts are extremely important, since trailing flight members are relying entirely on aircraft systems for station keeping. Altitude, heading, and airspeed contracts must be thoroughly briefed and understood in order to ensure mutual support and deconfliction.

10.4.1.1. System Updates. In order to achieve successful mission results at night, each flight member must monitor and correct individual system performance. During the mission planning process, enough steerpoints should be selected prior to the actual "Push" point in order to allow all flight members the opportunity to accomplish required system updates.

10.4.1.2. Sensor Tuning. In order to ensure the ability to find and destroy the target, cueing sensors must be tuned optimally. For TGP operations, select a steerpoint that adequately resembles the target. Plan on focusing the TGP in WIDE, NARO, and EXP. The TGP has two sets of lenses (1 for WIDE and 1 for NARO/EXP), so both must be focused. Starting at a point where target acquisition in WIDE FOV is anticipated, AREA track the steerpoint and turn on the "grey scales" in the TGP. Now use the slew button on the throttle to adjust the focus of the TGP. Change to NARO at a point approaching release slant range and focus the NARO lense. Approaching terminal lase slant range, select EXP and focus to the best pixel resolution. Since EXP uses the same lens as NARO, this step will only enhance the NARO focus. Generally, focus the TGP in WIDE from 15 to 10 NM, in NARO from 10 to 5 NM, and EXP inside of 5 NM. Subsequent steerpoints should be used to continue to fine-tune the Gain/Level requirements and focus of the TGP. Ensure the grey scales are off when focusing is complete. With a high system accuracy, TMS AFT, CZ, WIDE FOV to reduce the possibility of self-induced system errors. For fire control radar (FCR) operations, set the Gain/Level to provide optimum target/offset resolution and still allow accurate cursor positioning. Adjust the brightness to comfort.

10.4.1.3. Formations. Generally, en route admin formations should be relatively fluid, requiring minimum station keeping efforts, yet still provide acceptable mutual support. A technique is to fly a Compressed Trail formation to keep all trailing flight members the same distance from the preceding aircraft (**Figure 10.1.,** Compressed Trail). Spacing between flight members of 2 to 4 NM and offset up to 30 degrees allows adequate opportunity to accomplish navigation tasks and still allow time to monitor and correct spacing errors. Typically, night A/A tactical air navigation (TACAN) plans tie elements together (Number 1 to Number 2 and Number 3 to Number 4). Thus, wingmen have both the A/A TACAN and their radar to monitor range, while keeping visual using the FLIR. Positioning the preceding flight member just outside of the altitude or velocity scale in the HUD gives the desired horizontal offset. The trailing element lead can use the FLIR to monitor the preceding aircraft and maintain spacing by keeping the lead aircraft 6 to 8 NM on the radar. Altitude deconfliction is especially critical while flying in close proximity to other aircraft at night. While deconfliction is not required if a pilot is "FLIR visual," sanctuary altitudes must be briefed to ensure deconfliction when flight members are not visual. A technique is to 1,000 feet separation (within the block) between flight members as a default deconfliction method. Block plus flight position number is a way to ensure deconfliction. For example, if cruising in the 20,000- to 24,000-foot block, Number 1 would default to 21,000 feet, Number 2 to 22,000 feet, Number 3 to 23,000 feet, and Number 4 to 24,000 feet.

10.4.2. Marshaling/Holding. Typically, any plan with specific TOT contracts will require some form of force marshaling or holding. Marshal/hold points may be geographically and/or vertically deconflicted. Strict adherence to briefed contracts is critical, especially at night, to avoid conflicts within and between flights. For ease of maneuvering, maintaining the Compressed Trail formation allows the opportunity to keep the flight together as long as possible and minimizes deconfliction issues. Turns are generally comm-in on the discrete frequency. Blind deconfliction contracts must be adhered to since 180-degree turns at each end of the circuit will take preceding aircraft out of the HUD FLIR FOV until the turn is completed. The change to the ingress formation can be accomplished via either circuit timing extension or airspeed differentials to open the range between elements (if required). Aggressive maneuvering to open spacing should be avoided to reduce the possibility of wingmen losing FLIR visual and situational awareness (SA), as well as the possibility of spatial disorientation. When selecting a marshal/hold point, consider selecting a point which will allow a system update and sensor tuning in case the flight was forced to proceed directly to the hold point with no opportunity to accomplish the previously mentioned system/sensor tasks.

10.4.3. Ingress and Egress. Ingress and egress tactical considerations are exactly the same as in the day. Weather, threat layout, package composition/routing, support assets, and weaponeering are still the driving factors affecting the ingress and egress phase. The ingress and egress at night are complicated by the fact a pilot is literally blind except through the narrow FOV capability of the FLIR. Use of the radar and A/A TACAN is critical to maintain SA on the events occurring around and within the flight. Communication and maneuvering contracts are even more important at night than in the day. Threat reactions require disciplined communication and contract execution in order to maintain positional SA within the flight. Refer to AEM 3-1, Volume 5 for a detailed description of night threat reaction considerations. The most important consideration for night threat reactions is a well-thought-out blind/separated flight reform plan.

10.5. LANTIRN Attack Mission Planning Considerations.

10.5.1. Assumptions. In most cases, the TGP will be the primary cueing sensor for all air-to surface weapons due to the capability to precisely cue steering commands and the increased accuracy of laser ranging. The GM radar, while arguably a viable tool, is a back-up capability and it's utility will be a function of the weapon being employed and/or the capability to direct aim on the target. For system deliveries using radar cueing, a radar significant offset aimpoint (OAP) near the initial point (IP) usually offers the greatest chance for success. Additionally, though generally ROE dependant, delivering ordnance with a full-up system (HIGH/HIGH) and mensurated coordinates may be preferred over system deliveries using the radar for cueing.

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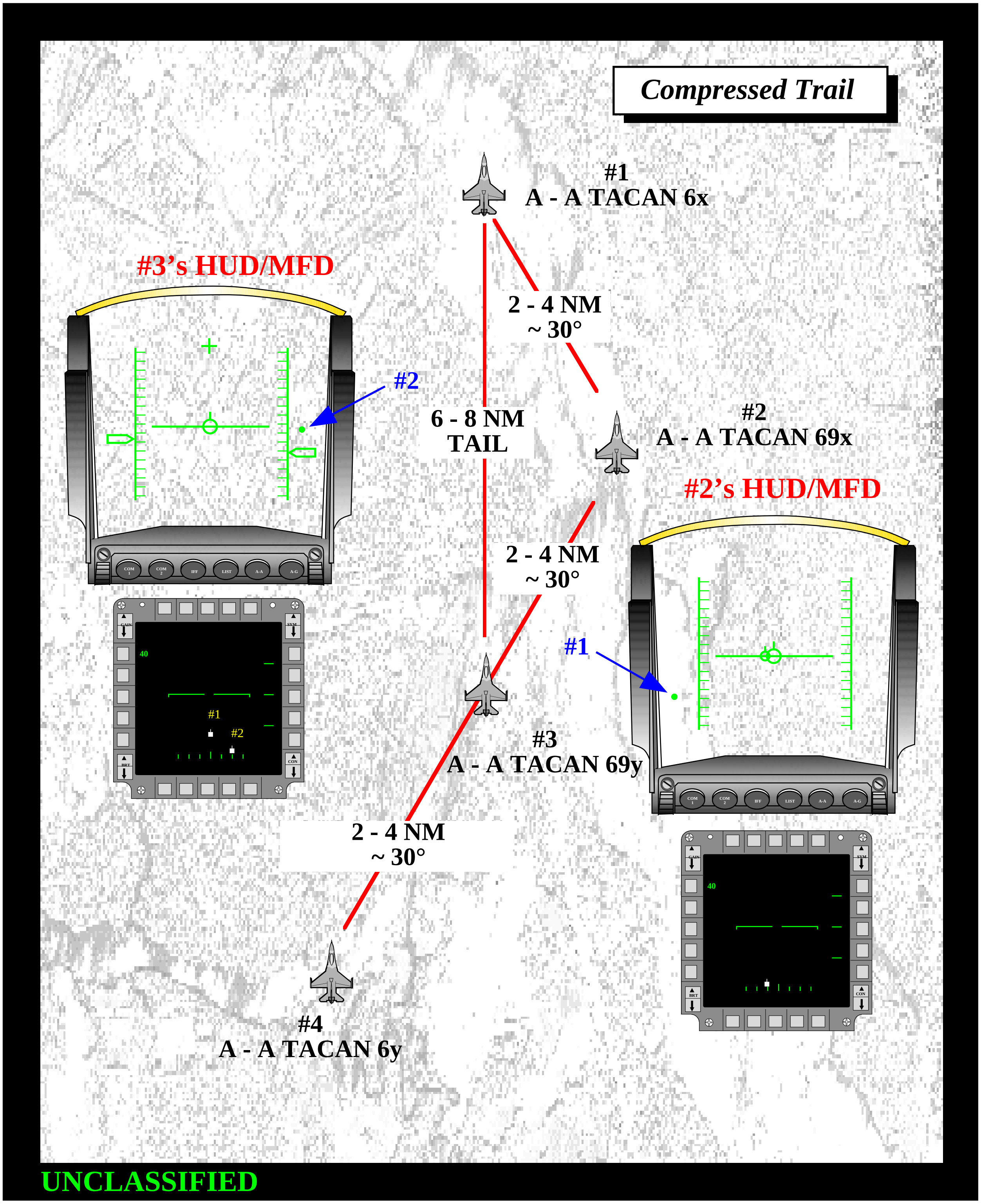
Figure 10.1. Compressed Trail.



10.5.2. Unguided Weapon Operations. Flying at medium altitude significantly reduces work load and may increase target acquisition range. The NVP, used by itself, has less potential for medium-altitude employment. The FLIR video on the HUD has lower resolution than the TGP display. This problem is compounded by longer slant ranges. For example, the slant range at which the center of the HUD FOV intersects the ground is 0.3 NM at 200 feet and 34 NM at 20,000 feet. The bottom of the HUD FOV (closest point) intersects at 0.1 NM and 12.0 NM, respectively. Recognition of only very large, thermally significant targets will occur at long slant ranges. However, medium altitude slant ranges are reduced significantly after roll-in for a dive delivery (3.3 NM from 30 degrees dive at 10,000 feet AGL), and the HUD can then be used to accomplish target acquisition and weapon delivery. Laser ranging using the TGP can help increase the accuracy of standoff deliveries such as loft as well as traditional level or diving deliveries.

10.5.2.1. Employment Considerations. Other considerations for medium-altitude unguided weapon employment are FLIR boresight, FLIR visibility, and winds. If TGP-equipped, the TGP can aid in DMPI acquisition and range update with both passive and laser ranging. GPS enhances system and weapons delivery accuracy.

10.5.2.1.1. FLIR Boresight. If performing a FLIR-assisted delivery (i.e., no TGP available), check the FLIR boresight during holding or ingress. Since the FLIR is normally boresighted to the top of the HUD on the ground, a FLIR boresight error may be noticed while airborne. The flight lead can establish a straight and level leg for flight members to perform a FLIR boresight update.

10.5.2.1.2. Sensor Bombing. Due to increased slant ranges and a combination of aircraft boresight errors, FLIR boresight errors, and small target size in the FLIR, a targeting pod, GPS, or fixed target track (FTT)-aided continuously computed release point (CCRP) delivery is more accurate than a CCIP FLIR delivery from medium altitude. To increase accuracy with CCRP, perform a ramp-down delivery to a 15- to 30-degree dive decreasing the slant range at release. The GMT/GMTT radar mode using a CCRP delivery is very effective from medium altitude when area munitions are used. For moving targets, the GMTT mode will provide lead steering based on the target's speed and direction of travel, while the CCIP mode requires the pilot to determine an appropriate lead point.

10.5.2.1.3. Common Errors. A common error during medium-altitude level CCRP deliveries is not anticipating the release point resulting in a late pickle, since the release point will be much further from the target at medium altitude. Cease all updates 2 NM prior to this point so there is time to center up the steering prior to release. If the actual flight level winds are predicted to be high, plan the attack to minimize crosswind effects. Allowing significant crosswinds to blow the F-16 off CCRP steering can prevent a release if the FCC computes the bombs will miss the target by more than 5,000 feet laterally. Consideration should be given to using drift cut-out during strong winds at release altitude to help get on steering. If possible, plan to attack with a tail wind to increase ground speed (GS). This will decrease exposure time to threats and minimize crosswind effects.

10.5.2.1.4. Delivery Parameters. For CCIP deliveries, maintain a stable G to stabilize the weapon solution. After pickle, continue to follow the vertical steering until bomb release. Do not exceed stores release G. Avoid exceeding 0.84 Mach during release since the weapons separation coefficients are not accurate beyond this airspeed. Target egress considerations are identical to other deliveries. With the reduced weight, climb to a higher altitude on egress for threat and fuel considerations, if possible.

10.5.2.1.5. Targeting Pod Use. Delivery of conventional ballistic bombs and cluster munitions at medium altitude is enhanced and simplified with the addition of the TGP. A CCRP solution may be obtained through point or area track of the target. In a fluid environment (targets in area, but precise coordinates unknown), DBS2 may provide initial target locations. Transition to the targeting pod at 10 to 12 NM and observe the area. Point or area track the target depending on target IR properties. Verify target environment through the FLIR and center steering. The laser fires when pickle button is depressed, and the bomb solution is updated using laser ranging to target. Due to previously mentioned FLIR inaccuracies, a TGP delivery is superior to a FLIR/CCIP accuracy from medium altitude (especially for HARB). However, aircraft boresight and accuracy of right hardpoint coefficients significantly affect the accuracy of ballistic TGP deliveries. As a ROT, ballistic TGP deliveries tend to drop long and left of the desired target. To reduce the effect of these hardpoint inaccuracies, area track the target to update system solutions, then break lock with the TGP prior to roll-in and release on steering. This technique is only valid with an accurate system altitude. With a system altitude error, maintain the TGP lock and continue to update with laser ranging.

10.5.3. Guided Bomb Operations. LGBs are freefall weapons equipped with a bolt-on guidance kit. The PAVEWAY family of weapons includes the GBU-12 (MK 82), GBU-10 (MK 84 and BLU-109), and GBU-24 (BLU-109 and MK 84) weapons. See TO 1-1M-34 for a detailed description of LGBs. The F-16 has the capability to self-designate targets, as well as Buddy Lase for other aircraft. Buddy Lase capabilities are also available from other sources such as Army Attack Scout helicopters and Navy/Marine attack aircraft. Special forces ground teams also have a lase capability.

10.5.3.1. Weapons Selection. If the decision is made to use LGBs, they need to be provided with the best possible solution concerning target acquisition and bomb energy. Plan attacks to provide sufficient energy (dive, medium-altitude level, or high-angle deliveries) to maintain adequate end game maneuverability.

10.5.3.1.1. The GBU-24 PAVEWAY III offers increased delivery accuracy, an expanded delivery envelope due to proportional guidance, and increased penetration capability due to trajectory shaping.

10.5.3.1.2. GBU-24 cannot be employed ballistically and must acquire a laser spot in order to hit the target. If the GBU-24 never sees the laser spot during altitude—hold midcourse guidance modes, it will impact well long (approximately 9,000 to 12,000 feet) of the target. If the GBU-24 fails to see the laser spot in any other mode, it may impact long or short of the target.

10.5.3.2. Target Selection. A point target, which requires a direct hit for target destruction (e.g., bridge, command post, hardened site, or aircraft shelter doors), is a good LGB target. The following considerations are essential in determining LGB use. It is critical to mission success that intel provides pilots with the most current, detailed target photographs and mensurated coordinates. Exact DMPI selection and final guidance is done with the NARO FOV of the TGP. This small field of regard necessitates good coordinates and the ability to do extended target study prior to flying the mission.

10.5.3.3. Aimpoint Considerations. Actual aimpoints will be driven by target vulnerability, reflectivity, visibility, wind, target motion, vertical development, and tactical employment considerations. The weapon must have an unrestricted LOS to the laser spot once guidance begins.

10.5.3.4. Target Reflectivity. Surfaces which exhibit specular (perfect) reflectivity (i.e., a smooth water surface, aluminum, or polished steel) are not suitable for designation and can misdirect laser energy and cause a miss.

10.5.3.5. Impact Angle. For steel or concrete targets, greater than a 70-degree (perpendicular to the target) impact angle will decrease the risk of broaching/ricocheting and increase the probability of success. For dirt covered targets, greater than a 40-degree impact angle will increase the probability of success.

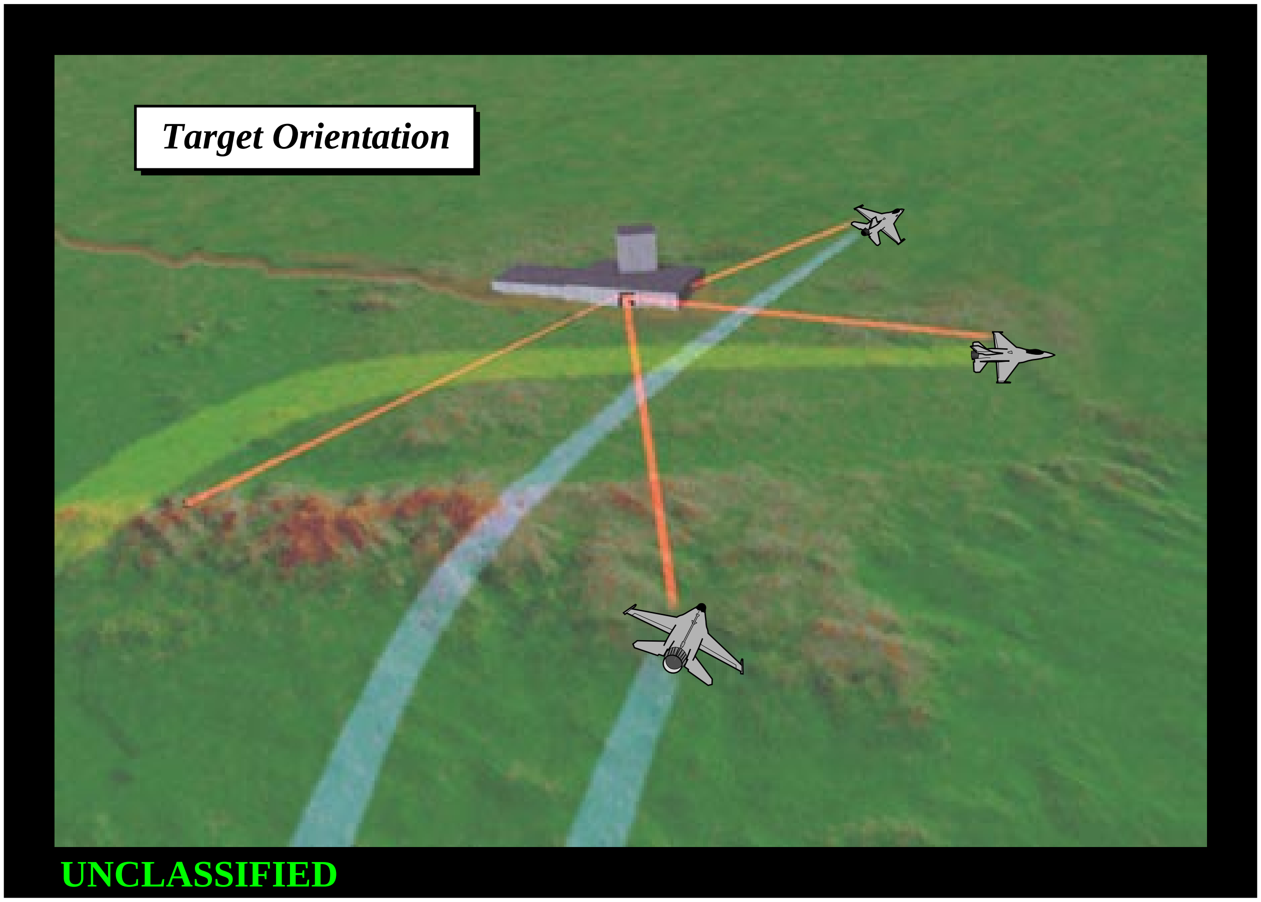
10.5.3.6. Target Orientation. If the target has vertical development, determine the orientation of the sides. Choose an attack axis which allows constant lasing on the side facing the weapon's flight path to avoid podium effect (**Figure 10.2.,** Target Orientation). Podium effect is the movement of the laser spot from one face of a target to another and can occur if the designator aircraft passes over or near the target. Worst case, the designator may be lasing a target face the weapon cannot see. Select delivery options and attack axis which ensure the laser spot will remain stationary during bomb time of fall (TOF). This is especially critical with the GBU-24's long TOF (**Figure 10.3.,** Podium Effect).

10.5.3.7. Obstructions to Visibility. Both the designator and weapon require an unobstructed LOS to the target during weapon TOF. Interference may be atmospheric (e.g., dust, smoke, haze, and clouds) or ground-based (e.g., trees, terrain, and buildings).

10.5.3.8. Cloud Base. Cloud bases are a major factor in determining the type of delivery. With the GBU-12, level deliveries are possible with ceilings as low as 1,000 feet AGL; however, 3,000 feet AGL is a more practical number. Standoff loft deliveries may be accomplished under relatively low ceilings, as long as pilots plan for at least 8 seconds TOF from laser-spot acquisition to impact. Patchy clouds in the target area can also cause the designator and the LGB to lose track. Minimum altitude for GBU-10 level releases should be 5,000 feet AGL, based on LGB maneuverability and impact angle.

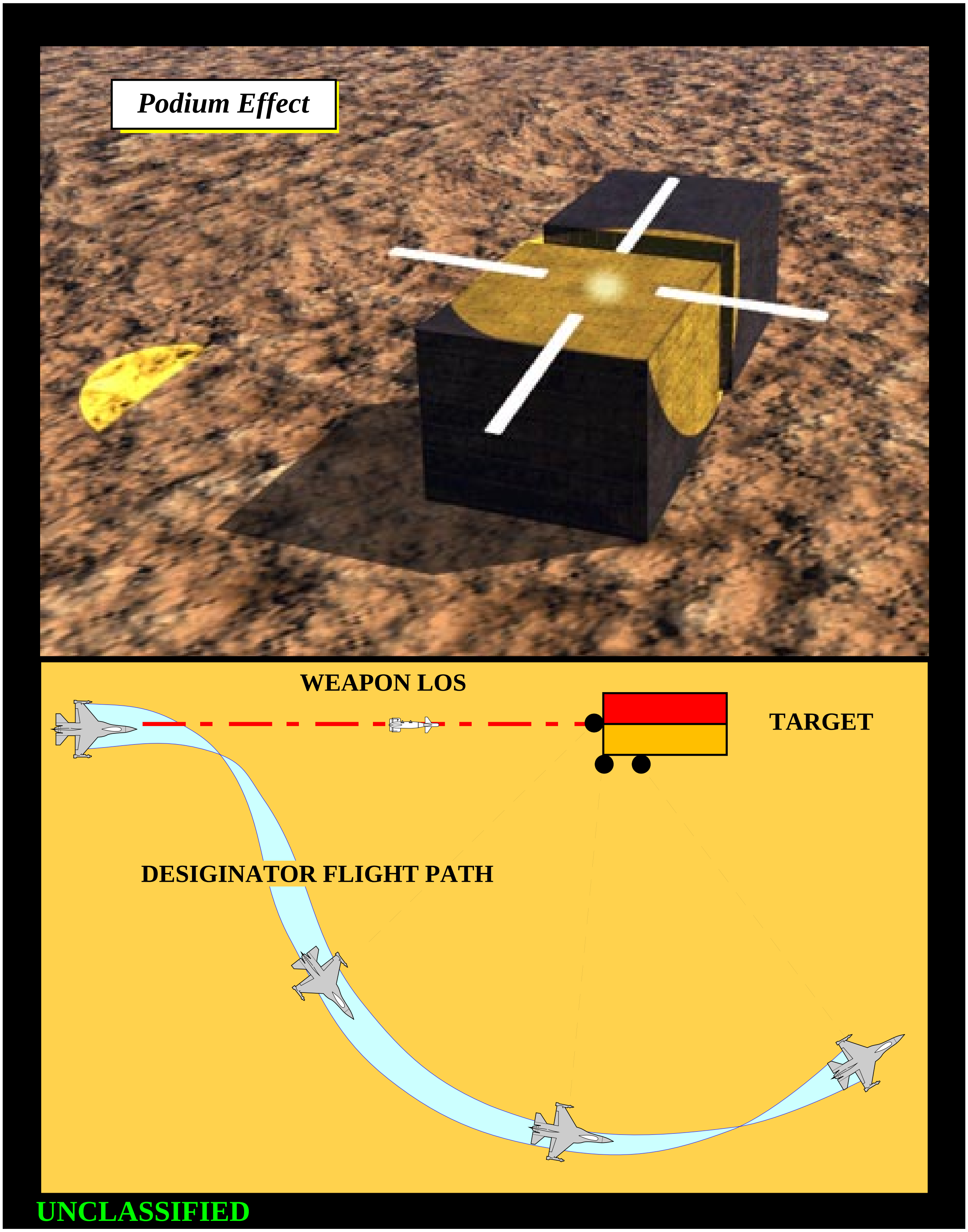
10.5.3.9. Ground Obstructions. Designator pilots must plan designation maneuvers to avoid ground obstructions or fly at an altitude which allows LOS over the obstruction.

Figure 10.2. Target Orientation.



10.5.3.10. Upwind Laser Aimpoint Correction. Give consideration to winds on the surface as well as release altitude. A/G Weapon System Evaluation Program (WSEP) data emphasizes that pilots should consider and apply surface wind corrections. Whenever possible, plan an axis of attack that will give a tail wind. If restrictions preclude this, take the average head wind and crosswind component from best available wind data (usually forecast) from ground level to 4,000 feet AGL at the target and aim upwind from the normal no wind aimpoint. The upwind aimpoint corrections should only be applied to targets that are large enough to maintain the laser spot on the target. The laser aimpoint should never be positioned off target even if the aimpoint correction exceeds target dimensions. The correction factor for GBU-12s is always upwind 1 feet per knot. The GBU-10 correction factor changes as wind speed increases. For GBU-10s, if the wind component is less than 20 knots, move the laser aimpoint upwind 1-foot per knot for a head wind (horizontal target only) or crosswind component. If the wind component is greater than or equal to 20 knots, move the laser aimpoint upwind 2 feet per knot. Due to increased performance, spot correction is generally not required for PAVEWAY III weapons. In any case, never move the laser spot off of the target!

Figure 10.3. Podium Effect.



10.5.4. Multi-Laser Environment. PAVEWAY II and III weapons were developed with pulse repetition frequency (PRF) coding to allow operations in a multi-laser environment while minimizing laser interference. PRF coding provides the ability to select the PRF the weapon will use for guidance. Therefore, PRF codes should be deconflicted between flight members.

10.5.4.1. If employing weapons using the same code and planning two separate targets, the aimpoints must be separated by enough distance to ensure only the desired spot is within the LGB FOV. **Figure 10.4.,** Weapons Acquisition Footprint, shows the shape of the FOV of a PAVEWAY II footprint on the ground for a 30-degree dive angle and 16,000-foot slant range (the PAVEWAY II nominal acquisition range).

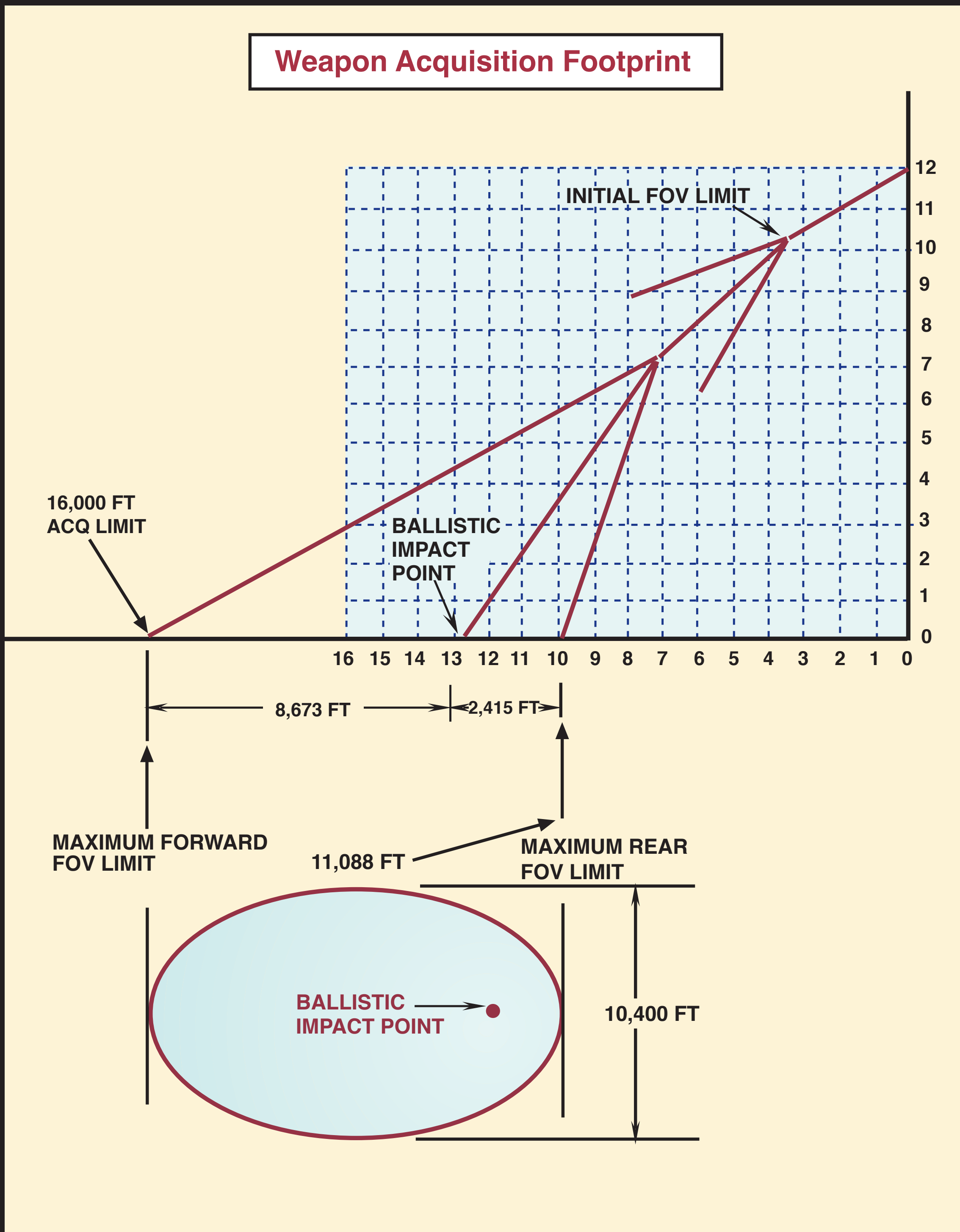
10.5.4.2. If two identically coded laser spots exist within the target area, there is no accurate way to predict which of the lasers the weapon will guide on. If two weapons are released from a parallel heading, their acquisition footprints must be deconflicted by distance to ensure proper targeting. As a ROT, 6,000 feet will provide adequate footprint separation so the desired target will be within each weapon's FOV. If the distance is less, the acquisition areas will overlap and it is possible that guidance will be to the wrong laser spot. Thus, if the aircraft headings converge, these targets must have greater separation so the acquisition footprints do not overlap. The primary method for deconfliction in the same target area should be different PRF codes.

10.5.4.3. As the dive or loft angle decreases, the length of the footprint increases and so does the minimum required distance between targets. The allowable tolerance on the weapon's FOV, delivery system dispersion, actual range at acquisition, final attack geometry, and timing of the delivery are all variables that must be considered when deriving the distance between targets. For PAVEWAY II attacks with parallel headings, a minimum of 6,000 feet between targets is required. For headings that converge at 45 degrees, allow 6,600 feet; and for 90 degrees opposing attack axes, allow 8,200 feet. If the targets are closer, then separately coded weapons should be used.

10.5.5. LGB Enhancement Techniques. The capability of LGBs to guide to a direct hit depends on a number of variables. The most crucial variable is the weapon's airspeed during its guided flight, particularly during low-altitude employment. LGB airspeed is a function of release angle, release airspeed, density altitude, and position at weapon acquisition. The following techniques increase the $PH_{(HIT)}$.

10.5.5.1. Release Airspeed. Use a release airspeed as high as release limits and aircraft capability allow, especially at lower altitudes and with GBU-10s. This gives the LGB maximum energy at acquisition and maximum maneuverability during guided flight. PAVEWAY II weapons dissipate large amounts of energy while guiding. Therefore, the longer the guidance time, the more energy lost. Giving the bomb enough energy to generate 2 Gs during the last seconds of flight is required for success. Airspeed is also a major factor in release range of a GBU-24 providing a longer standoff capability. TO 1-1M-34 provides in-depth information on LGB maneuverability versus airspeed.

Figure 10.4. Weapons Acquisition Footprint.



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10.5.5.2. Vertical Development. Elevating the laser spot on a vertically developed target will increase the probability of the weapon impacting the target. If a ground-level target is designated, a short weapon impact may result due to the flight characteristics of LGBs.

10.5.5.3. PAVEWAY II Designation. Delayed lasing is required for low-angle loft of PAVEWAY II LGBs. If the target is continuously lased, the LGB attempts to fly directly to the laser spot and flies below the required ballistic trajectory. Minimum loft angles of 25 degrees (GBU-12) or 30 degrees (GBU-10) will ensure bomb apex occurs prior to laser spot acquisition. With less than 30 degrees of dive, the bomb will lose energy during guidance. The result is the LGB tends to impact short for shallow-angle deliveries. To minimize this problem, the laser should be active only during the last 8 seconds of the weapon's TOF. More than 8 seconds of laser guidance dissipates large amounts of weapon energy, resulting in degraded performance.

10.5.5.4. PAVEWAY III Designation. PAVEWAY III weapons are maximized for standoff deliveries with continuous lasing. Continuous lasing will allow the weapon to fly its best energy conserving and maximum range profile. In some atmospheric conditions, the GBU-24 may not be able to acquire the laser energy at extended ranges. In these cases, the release range needs to be adjusted to account for delayed lase profiles. The TGP will allow this technique at medium altitude.

10.5.5.5. Slant Range versus Graze Angle. At long slant ranges or low-graze angles, the laser spot will disperse in an oval pattern on a flat surface. However, even from a 30,000-foot slant range 500 feet above the target, any vertical development will provide a "hot spot" of laser energy and allow weapon guidance.

10.5.5.6. Mission Planning. Current photographs and detailed maps must be used in mission planning. This is especially critical to "buddy" designation when the designator and bomber must be certain of the correct target without radio communication. Planners must account for obstructions to LOS which will dictate the altitude required for the designation maneuver. Cloud cover determines what type of delivery is available to the pilot. Obstructions to visibility (i.e., smoke and dust from ordnance in the target area) must not interfere with either the designator or LGB LOS. Therefore, for an attack with multiple LGBs, it is essential that the pilot consider wind effects on smoke and debris in the target area.

10.6. Low-Altitude LANTIRN Employment. Specific mission planning and employment considerations which are specific to the low-altitude environment are discussed in this section.

10.6.1. Mission Planning. Planning for night LANTIRN ingress and employment is significantly different from daytime planning. This is primarily due to reduced cockpit lighting and system limitations.

10.6.1.1. Turn Radius/Limited Turn Capability. When flight with LANTIRN at low-altitude is conducted within terrain following (TF) limits, turn radii increase dramatically over typical daytime navigation turns. Plan turns using 45 degrees of bank to ensure they can be accomplished within TF limits. Turns into terrain will further limit turn capability. The turn radius must also be used when drawing your map to aid in route study of where the aircraft is actually going to fly. For turns where large heading changes are required, it may be desirable to plan to lead the turn in order to roll out in more favorable terrain. If overflight of the steerpoint is desired, offset from the inbound track opposite the direction of turn. Intermediate steerpoints may be required solely to reduce turns at important points such as the IP.

10.6.1.2. Start-Route/Letdown Point. Plan to complete all cockpit tasks before descent at the start route point. Consider using altitude deconfliction until past the start route point. Whenever possible, enter the low-level regime over an easily identifiable point. Flat terrain allows a smoother transition to low altitude.

10.6.1.3. Steerpoint Selection. For low-altitude operations, avoid excessively long legs. If circumstances dictate longer than 10 minute legs, consider a midpoint position/altitude update point (OAP).

10.6.1.4. Stick Charts. Navigating using a typical visual flight reference (VFR) map becomes unmanageable at night with lower cockpit lighting. Stick charts are used as a refresher to route study. Stick charts do not remove the MCI 11-F16V3, *Pilot Operational Procedures—F-16*, requirements to carry a VFR map. Development of a stick chart is an individual process to aid in mission study and in-flight reference. Each pilot has a different idea of what is significant for each leg of the route. However, the minimum items normally included on the map are: times, distances, headings, attack parameters, route abort altitude (RAA), and MSA. Optional data on the stick chart includes: significant points, obstacles, and any required cockpit tasks or useful information. **Figure 10.5.,** Stick Chart Example, shows a typical hand-drawn stick figure map.

10.6.2. In-Flight Operations. Using the FLIR/TFR during flight can greatly improve overall SA, but confidence in the system must be reinforced by in-flight checks and in-depth systems knowledge.

10.6.2.1. TFR In-Flight Check. Prior to initiating TFR flight, it is imperative to check the operation and integration of the TFR, radar altimeter, and digital FCS. This check is accomplished IAW the Dash 34 and in an area of known elevation and relatively flat terrain. After a night takeoff, and the jet is cleaned up, do not forget to turn the HUD FLIR up so checks are not done in a black hole. The TFR check can be very task intensive depending on airspace limitations, currency, etc. Make sure you are mentally prepared. Do not continue TF operations until assured of correct system operation. **Table 10.4.,** RATSIMPL Cockpit Check, may be useful to complete the TF check and prepare for the next phase of flight.

Figure 10.5. Stick Chart Example.

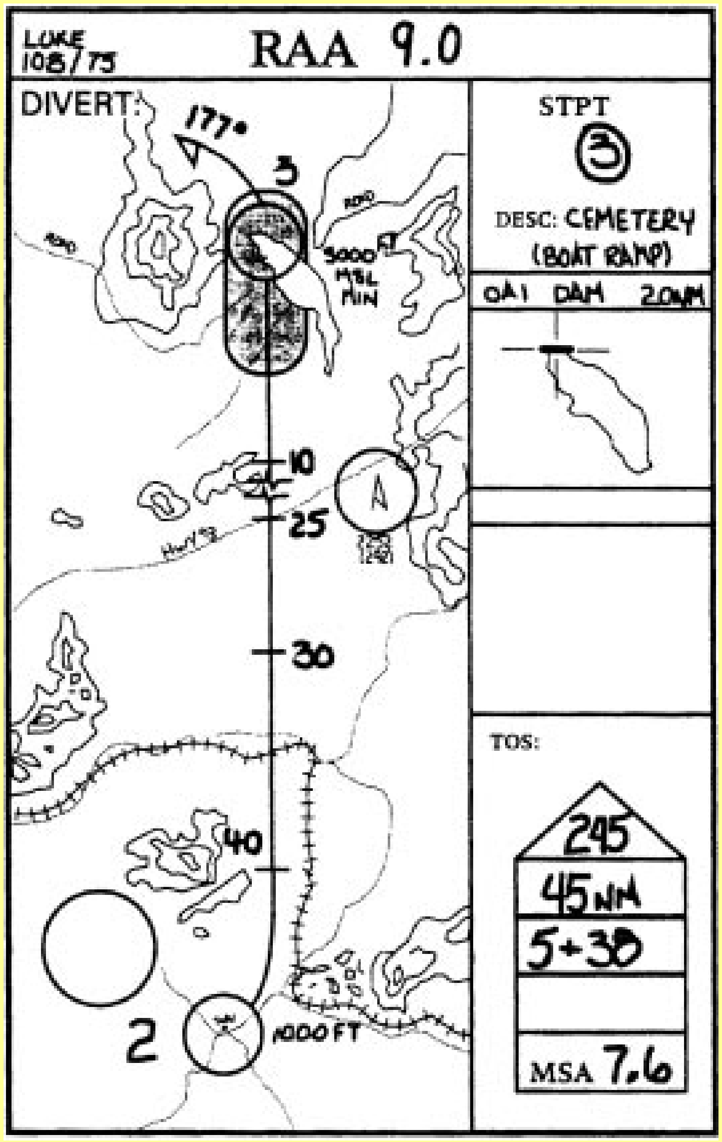

Table 10.4. RATSIMPL Cockpit Check.

RATSIMPL Cockpit Check
R - Radar altimeter - ON and operating after SWIM check
A - ALOW - 900 feet set
T - TACAN - REC
S - SCP - 1,000 feet set
I - IFF - as required
M - Missile - COOL
P - Pod - unstow TGP
L - Laser arm - as required
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10.6.2.2. En Route Cruise. If the mission includes air refueling or a medium-altitude cruise segment prior to low-level letdown, put the TFR in STBY or Blended. Putting the TFR in STBY will allow you to fly formation without getting fly-ups and at slower airspeeds without the flashing limits symbology. Flying with flashing limits is a bad habit pattern to establish because it may desensitize you to the warning. The Blended mode may also be useful. It is selected by turning the autopilot on with the TFR in any mode other than STBY. If altitude hold is used Blended will maintain the aircraft altitude while still giving you TF fly-up protection. Be aware that even if the AMS switch was in AUTO TF when you selected the autopilot function, the AMS will revert to MAN TF when you come out of Blended by deselecting the autopilot. If you exit the Blended mode by depressing the AMS switch, the autopilot will disengage and the system enters AUTO TF. AUTO TF combined with rough terrain or a little turbulence can be an excellent foreign object damage (FOD) generator. This is your last chance to arrange your cockpit prior to the ingress phase. Make sure you are strapped in tight and that maps, charts, and lineup cards are secured and in a usable order. Remember at night things will be harder to read. Consider writing bigger and darker and using different colors than you may be used to on day missions.

10.6.2.3. TFR Modes of Operation. The TFR has six modes of operation from which you can choose: NORM, LPI, STBY, WX, ECCM, OR VLC (see **Table 10.5.,** TFR Operation Modes). Choosing the appropriate mode varies from mission to mission based on the weather, terrain, and threat environment. Knowing the basics of each mode helps you choose the best mode for mission execution.

Table 10.5. TFR Operation Modes.

TFR Mode	Description
NORM	This mode is usually planned for mission segments in all types of terrain, low threat, and good weather.
LPI	LPI. Selected via the TFR page on the MFD or the run quiet switch and is usually used on longer/straight legs where minimum maneuvering is required and potential threats are present.
STBY	Stows the TFR antenna and should be used on the ground and airborne only when TF fly-up protection is not required/desired.
WX	The TFR processed data is reduced from 36,000 to 15,000 feet in front of the jet and the TFR look-up angle is reduced from 10 degrees to 5 degrees. You may notice a degraded capability to detect man-made objects and low reflective surfaces. Select the WX mode if clouds and/or actual precipitation are along the flight route. This does not guarantee a weather fly-up, but it improves the chances for smooth sailing.
ECCM	The TFR processed data is also reduced to 15,000 feet. This mode allows for operation in an ECM environment where numerous threats might be encountered. All other information is classified.
VLC	Enter VLC by selecting 100 feet SCP on the TFR page. Initial commands will be to 200 feet until the terrain data criteria is met for 100 feet SCP. If the terrain does not continue to meet system requirements for 100 feet, the SCP automatically bumps up to 200 feet and the jet climbs to 200 feet. A DMS forward anytime you are at 100 feet changes the SCP to 200 feet and climbs the jet. VLC is normally used in high threat, relatively flat terrain, where maneuvering is minimal.
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10.6.3. Low-Level Operations. Executing the low altitude LANTIRN mission can be very hazardous if daytime habit patterns are carried over. Particular care must be given during the initial descent and high tasking periods of the mission.

10.6.3.1. Prior to TFR Letdown. Before initiating an AUTO TFR letdown, review all your planned data including TOT adjustments, terrain elevation, RAA, leg MSA, and minimum airspeed. Ensure all LANTIRN systems are on and functioning properly prior to beginning low-level operations (ALOW set 90 percent of SCP, CARA ON, TFR out of STBY). Take the time necessary to ensure the systems are operating properly and that you are prepared for the transition to low altitude. Rushing this transition may lead to task saturation that may prove to be fatal. **Table 10.6.**, RTFAM Check, may help remember major required tasks.

Table 10.6. RTFAM Check.

RTFAM Check
R - Radar altimeter - ON
T - TFR - appropriate operating mode
F - FLIR - on HUD
A - AMS - auto engage
M - Monitor
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10.6.3.2. TFR Letdown. The initial TFR letdown must be monitored to ensure proper system operation. Things to watch include dive angle does not exceed 12 degrees in an AUTO descent, the E2 scope has processed data displayed, the combined altitude radar altimeter (CARA) is decreasing properly, and that the aircraft initiates level off for the SCP selected. Initially set the stores control panel (SCP) to level off at 1,000 feet. After initial level off and verifying proper system operation, reset the SCP as required for the mission.

10.6.3.3. Tactical Navigation. Doing systematic checks at each steerpoint helps maintain SA. Setting the leg course in the course deviation indicator (CDI), setting the next heading with the Captain's bars, reviewing the update plan, checking gas, and clearing on the radar are some examples.

10.6.3.3.1. Given the limited FOV the FLIR gives you, it becomes even more imperative that the INS and system altitude be kept as tight as possible. Obviously, a HIGH/HIGH status is a wonderful thing and can greatly reduce your cockpit work load. Without GPS high accuracy valid slews are normally entered into the system to improve the KALMAN operation.

10.6.3.3.2. Due to changing conditions, you will probably also need to adjust FLIR Gain, brightness, and contrast along the route. The TDA may help anticipate areas where higher Gain may be required. The bottom line is to adjust the picture to make it work best for you. Auto Gain is always an option.

10.6.3.3.3. As you become more comfortable and proficient, you must guard against complacency when using the TFR LANTIRN system. Maintain the cross-check that you established in the day VFR low-altitude situation work load of cockpit data and rocks. When your GPS is not working and you must do manual fixes and ACALs, pacing and prioritization become critical. Knowing where, when, and how to do a fix is essential. Try to minimize time in the FIX modes and maximize A/A radar search time. For FCR modes, use the GM cursor for 6/12 slews and if the point can be brought near the HUD center, use the HUD diamond/OAP symbol for 3/9 slews. One technique for visual modes is to start a slight climb to aid in turnpoint identification and increase air-to-ground ranging (AGR) slant ranges for better accuracy. In any case, do not enter the FIX/ACAL update until you have checked your deltas and are satisfied with the correction.

10.6.3.4. Terrain Masking. Thorough route study prior to flight is imperative. Knowing where high/rough terrain is will allow you to follow the path of least resistance to optimize terrain masking. Use a combination of the FLIR and flight path marker (FPM) to help you terrain mask. In mountainous terrain, look long-range in the FLIR for saddles in hills or the path of least resistance. Point the jet via the FPM, and use look-into-turn and snap-look to aid your decision.

10.6.3.5. Fly-Ups. Should a fly-up indication occur, roll to wings-level and allow the system to increase pitch until reaching a 20-degree climb. If the system resets before reaching 20 degrees, you may allow it to descend while verifying normal operation. At 20 degrees, depress and release the paddle switch. If this resets the system, verify normal operation and descend back to low-altitude. If the paddle switch did not reset the system, hold the paddle switch and level above the MSA/RAA. If the malfunction can not be cleared, TFR operations can not be continued. Cease low-level operations and continue at the MSA. Once established at the MSA, determine whether or not to continue with the mission or RTB.

10.6.3.6. Low-Altitude Threat Reaction Considerations. At night, weapons explosions and secondaries from anitaircraft artillery (AAA) and surface-to-air missile (SAM) launches can be very disorienting. Having a solid cross-check and threat reaction game plan is essential. The aggressive maneuvers normally associated with threat reactions can be very disorienting at night. The maneuvers must be performed using aircraft references unless the horizon is clearly visible without reference to the FLIR. It may be more important to maintain orientation than to defeat a threat that may not be targeting you. Since you cannot easily monitor other aircraft in the formation during a threat reaction, it is important that reacting pilots communicate information such as reference headings, altitudes, and type of reactions to other flight members when initiating a threat reaction. During all threat reactions, dispense chaff and/or flares as required and use electronic countermeasure (ECM) as required to degrade radar or missile capability.

10.6.3.7. Station Keeping Considerations. Station keeping consideration are identical to the medium-altitude considerations. There are several options for low-altitude threat reactions commencing below the MSA. The first option may be simply to select a lower SCP and check away from the threat. Use direct and indirect terrain masking to help deny acquisition. The second option is initially a climb to or above the MSA followed by maneuvering as required. This option can be used in cases where you have sufficient time after your initial threat indication to execute the climb and reaction prior to engagement. The final option is a 30- to 45-degrees bank oblique turn from below the MSA to an altitude at or above the MSA. If you pull more than approximately 2.5 G in a left turn or 1.7 G in a right turn you will exceed TF limits. Once reaching the MSA, over bank to approximately 90 to 120 degrees of bank and pull as required to the new heading. While in a low-altitude notch maneuver, a technique to dispense chaff with G on the jet is to momentarily pull up to 5 to 10 degrees nose-high with 3 to 4 G while simultaneously dispensing chaff. Release the stick immediately after dispensing chaff and the auto TFR will bring you back down with minimal exposure. This technique is sometimes referred to as a "porpoise."

10.6.4. Low-Altitude LANTIRN Attack Options. The TGP provides an excellent capability for the delivery of both guided and unguided munitions. TGP passive and laser ranging combined with an accurate navigational position and system altitude, provide a significant improvement in weapons delivery accuracy for unguided munitions.

10.6.4.1. System Updates. GM radar and visual slews can be used as a verification of GPS accuracy or as a backup for cases when GPS or coordinate accuracy are uncertain. Extensive knowledge of what you expect the target to look like and using all available sensors will help to defeat the enemy's camouflage, concealment, and deception techniques. If GPS is not available or GPS ACAL is not used, an ACAL should be accomplished in the target area. Ideally, a pre-IP should be used to update the system and provide attack axis alignment. If the TGP can be slewed to the IP, RP, or an OAP, your steering to the target will be updated. Laser ranging can be used to update height above target. You can also use the pop dot as a head-up reference for your pull-up or action point. Airspeed is a critical factor during climbing maneuvers. Ensure you accelerate as planned or you may not be able to execute the attack.

10.6.4.2. TGP/LGB Loft. The loft delivery with the TGP/LGB combination (**Figure 10.6.,** TGP/LGB Loft) provides both target stand-off and precise guided weapons delivery. Ideally, the LGB should be lofted upon mensurated coordinates with nothing but GPS to aim the system. Without GPS, a precise update on an accurate IP should be performed; and nothing more until after the LGB has been lofted. The problem is that at low graze angles and long distances, there is little Delta T for the TGP to Area track. Area tracking the DMPI prior to release will therefore result in a wandering TGP. Furthermore, the Area track crosshairs cannot be accurately placed over the DMPI from low graze angles and long distances. Attempting to do so will impart an erroneous 2 to 3 mil error which will become significant during the guidance segment of the loft. If a DMPI has enough vertical development and Delta T, then it can be Point tracked during the IP-to-target run without any problems, until the loft pull-down when it will revert to Rates and impart an unwanted slew. Regardless of track mode, lasing the DMPI from low graze angles and long distances will always impart an incorrect range to the system as it is too easy for the laser to miss the top of the DMPI by 1 mil and range-in several thousand meters long. The only acceptable answer is to Point track the DMPI—without lasing it—and break lock prior to release.

10.6.4.2.1. TFR Attack Modes. There are several combinations of TFR modes that can be used to loft an LGB. The old method is to use MAN TFR for the run-in, pull-up, and recovery. This requires 100 percent of your attention be devoted to the FPM and MAN TFR box. Another method is to remain in AUTO TFR throughout the loft maneuver. As long as you roll to beyond TFR global limits in less than 2 seconds, no fly-ups will result. This technique is good because you remain within AUTO TFR protection for a longer period of time. However, during the pull-up you will be fighting the AUTO TFR which is constantly attempting to pull you back down to the selected SCP. Furthermore, the AUTO TFR will descend you 12 degrees nose-low during the LGB guidance segment, unless you manually hold the nose up. Another technique is to use ALTITUDE HOLD Blended mode for the LGB guidance segment of the loft. This is good in case of terrain or podium effect problems, but the aircraft vulnerable since it does not descend to low-altitude quickly. A final technique is to engage

ATTITUDE HOLD Blended mode when inside the IP, level at the SCP. Remain in Blended throughout the loft maneuver; this will resemble AUTO TFR in the HUD and provide AUTO TFR protection. No back pressure will impede the pull up as you are not in AUTO TFR. No fly-ups will occur as long as you roll to beyond TFR global limits within 2 seconds. The LGB should be lofted at an angle between 30 to 35 degrees nose-high. Either the programmed loft angle and HUD climb cues can be referenced, or the constantly computed loft angle displayed next to the altitude scale in the HUD can be referenced.

10.6.4.2.2. After LGB release. After LGB release, always reference the target MSA prior to rolling to 135 degrees of bank and pulling down—not across the horizon—with 4 G to 5 degrees nose-low. Roll out wings-level at 5 degrees nose-low and keep your attention in the HUD until you see the ATTITUDE HOLD Blended TFR line below the FPM. A SWIM fly-up is not uncommon at this point if the RALT times in prior to the TFR. If this happens, paddle and release very quickly. To adjust the descent angle, simply place the FPM where you want it. Paddling to adjust the attitude-hold descent angle is not required. You will now have a 5-degree nose-low descent for LGB guidance—much improved LOS to the DMPI—without diverting any attention or effort to manually holding back stick pressure. Once the attitude hold blended TFR line is visible beneath the FPM, without any switch changes, devote your attention to the TGP display to acquire and track your DMPI. If you see masking indications, then simultaneously bank away from the target (5 degrees of bank or less) and depress the AMS to descend at 12 degrees nose-low. Track the DMPI prior to laser start time. Minimize slews when the laser is firing and the LGB guiding. However, if the TGP wanders off the DMPI, put it back on. If still descending at 5 degrees, once the LGB detonates engage the AMS and have the AUTO TFR bring the aircraft down more quickly to the low-level structure. At this point there is sufficient attention and time available to devote to flying precise egress headings and regaining FLIR visual with your leader.

10.6.4.2.3. TGP Masking Considerations. Since the TGP is mounted on the right chin station, left turning egresses reduce the risk of a mask prior to weapon impact. Right turning egresses are possible, however they are less tolerant of poorly executed escape maneuvers. If the situation permits, delay your descent to low-altitude until weapon impact to help maintain LOS to the target. Blended attitude or altitude hold may reduce task loading in this situation.

10.6.4.3. TGP/LGB Fly-Up Attack. If threats and the situation dictate, you can execute a fly-up attack to a level LGB delivery above weapon frag envelope. The fly-up allows a better view angle to the target and much easier target identification. Commence the fly-up at a range and angle that will allow enough time for TGP track and range update prior to release. Execute the egress the same as in a loft delivery (**Figure 10.7.,** TGP/LGB Fly-Up Attack).

Figure 10.6. TGP/LGB Loft.

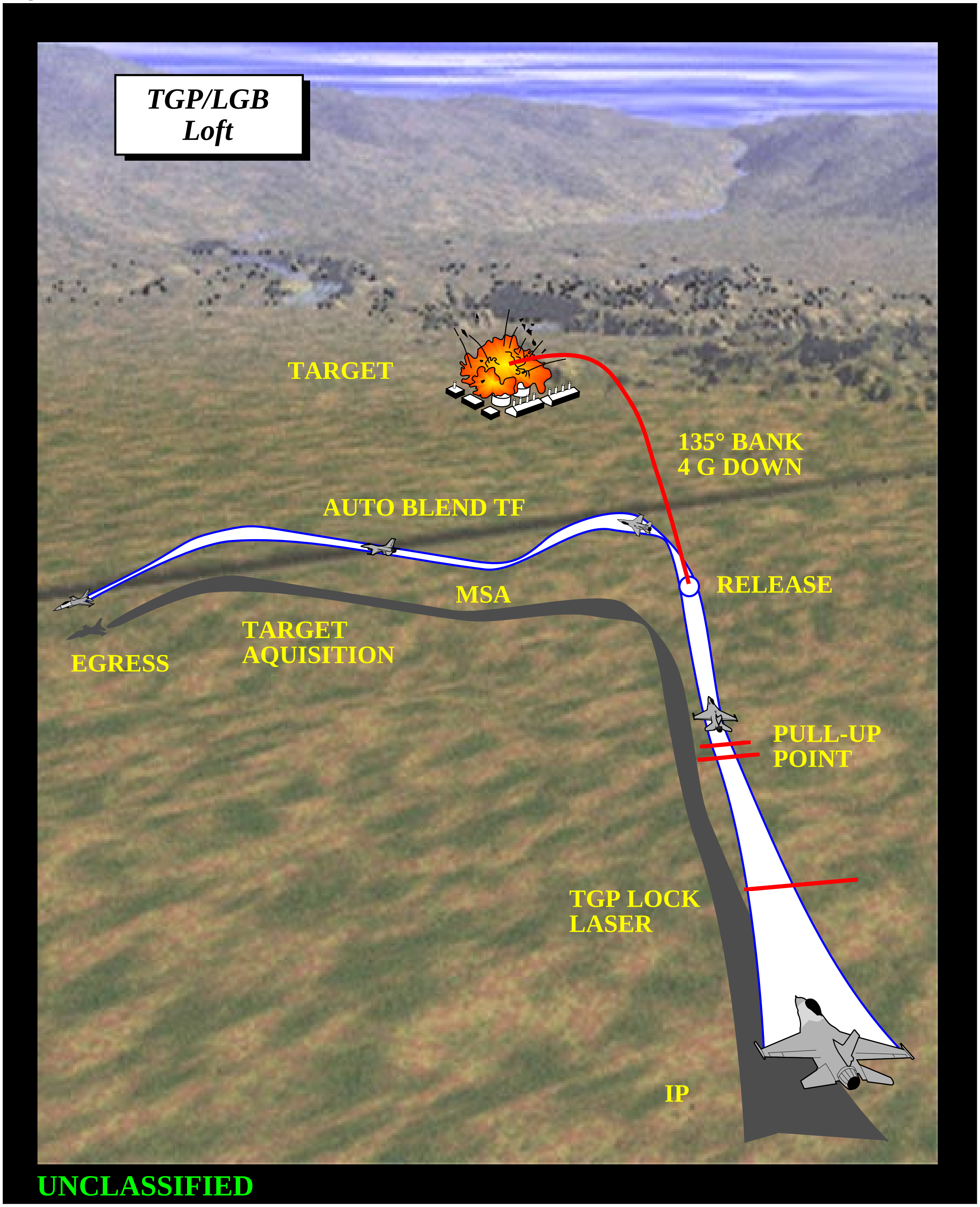
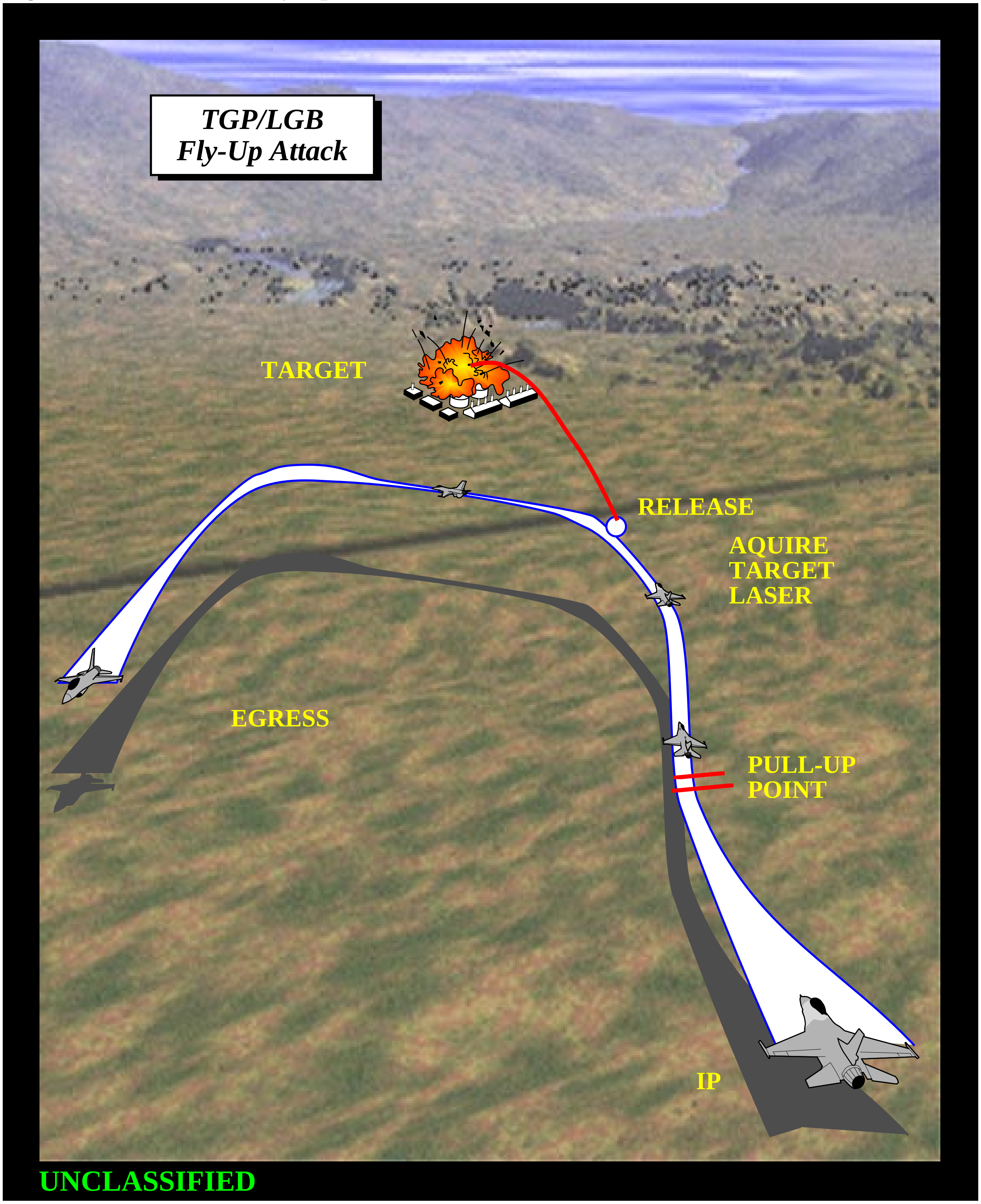


Figure 10.7. TGP/LGB Fly-Up Attack.

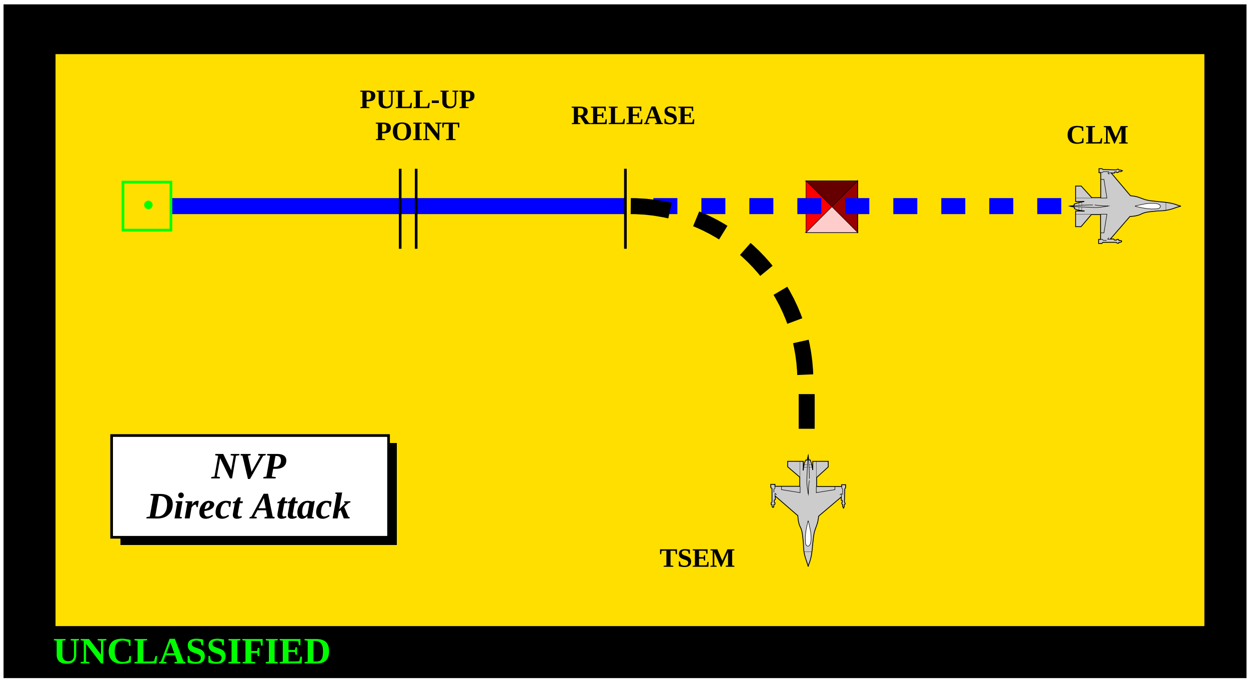


10.6.4.4. Unguided Weapons Attacks. The TGP/FLIR system allows for LDGP and CBU weapons attacks with accuracy approaching that of daytime operations. Attack selection varies based on expected target acquisition ranges, coordinate accuracy, and weapon impact requirements. Expected cloud bases and visibility also must be considered.

10.6.4.4.1. TGP/LDGP Loft or Fly-Up Attacks. If delivering unguided conventional weapons the TGP provides an excellent target identification and update capability. Loft execution through weapons release is identical to the LGB delivery. Since the weapons are unguided, there is no requirement to track and lase the target after release. Since a TGP lock is not required, you can also increase the G in your escape maneuver to 5 G. The important thing to stress here, however, is to not do any head down tasks prior to being in AUTO TF. If the target is visually acquired on a TGP assisted fly-up or direct attack and CCIP is selected, the TGP will break track and follow the pipper.

10.6.4.4.2. NVP Direct Attack. The direct pop provides an attack option for cases where stand-off deliveries are impossible or not desired (i.e., TGP failure, non-PGM, weather) (**Figure 10.8.,** NVP Direct Attack). Select AG/CCRP and use the TGP/FCR/HUD FLIR to acquire the target. When conditions prevent target acquisition, rely on INS/GPS (break lock and cursor zero TGP/FCR) approximately 2 NM from action point and concentrate on the direct attack (HUD). Select MAN TF approximately 2 NM from your pull-up point. At the pull-up point, establish desired climb angle using the HUD FPM. There are two options for establishing the desired dive angle after reaching pull-down altitude. The first option is a 180-degree roll and pull. At planned pull-down altitude, roll the aircraft 180 degrees and pull straight down with 3-G. Do not attempt to correct steering inverted. At 5 degrees prior to the desired dive angle, reduce G and roll upright. Roll out in the same direction as the initial roll-in to minimize offset from the steering line. Adjust dive angle and the bomb fall line (BFL) as required. A SWIM fly-up may occur during this maneuver since the RALT may be slow to reacquire the ground prior to establishing TF limits. Another option is to perform a bunt at the pull-down altitude. For this attack you can remain in AUTO TF the entire time. At the push-down altitude the AUTO TFR will perform a perfect 0.2 G bunt if you just let go of the stick. Since the G during this maneuver is lower the pull-up point is farther from the target. Use caution when correcting for steering errors during the bunt. If you use negative G during the bunt, lift vector is out the bottom of the aircraft. To correct towards the vertical steering line, bank away from the line during the bunt. If this is too confusing, wait until after establishing aim-off distance (AOD) and make normal steering corrections. Abort the pass if parameters are not met. If you acquire the target, select CCIP for weapon release. Select CCIP at least 3 to 4 seconds prior to desired release to avoid having an unusable pipper as it does its initial AGR. Remember that AGR and FLIR boresight errors will affect bombing accuracy with CCIP. If the target is not apparent in the HUD, deliver ordnance in CCRP (bomb the TD box).

Figure 10.8. NVP Direct Attack.



10.6.4.4.3. Level Delivery. A level delivery provides a capability for high drag weapons employment when target acquisition may be limited, the pull-up point was missed or could not be identified, or with systems failures such as a HUD failure. Approaching the target, climb above computed MRA. Do this by either; remaining in AUTO and selecting a higher SCP, by pulling up and selecting blended TF, or by selecting MAN TF and climbing. Since MAN TF requires more concentration it is not recommended. If you can, acquire the target with the FCR or the TGP prior to release to use radar or laser ranging to update your weapons release solution. Without accurate HUD FLIR aiming, the best delivery option is a CCRP level. If you can only acquire the target in the HUD FLIR, use a CCIP delivery.

10.6.4.5. MAVERICK Attacks. The TGP simplifies low-level MAVERICK employment and allows multiple shots per pass. Even without a TGP, the Block 40 F-16 has the capability to lock two Mavericks to separate targets prior to release and provides missile slaving through either HUD slews tied to a TD box or FCR slews tied to the GM/GMT radar cursors. Based on the forecast detection range, bump up for LOS to the target. Do this like the level delivery discussed in **paragraph 10.6.4.4.3**, Level Delivery. MAN TF may be selected just prior to launch. Use the FCR/TGP to identify your target. If using the TGP, simply Point track the target with the TGP to commence the missile hand-off. If the MAVERICK has not correlated, TMS right to reattempt hand-off. Use the WPN MFD page to verify correct MAVERICK hand-off. Cross-check range to the target prior to handing off a second missile. Once both MAVERICKS are locked, shoot each missile individually. Verify weapon track on the WPN page between shots. Since it is required that the pilot select the weapon as the SOI and adjust polarity prior to track without the TGP, it demands more time and may prevent a multiple launch opportunity. After launch, based on range to the target, either execute an in TF limits turn or climb to or above MSA and execute a 4 to 5 G escape maneuver to the initial egress heading.

10.6.5. Escape Maneuvers. At night, treat the escape maneuver like an instrument maneuver. Concentrate on HUD and instrument references, especially bank and climb angle.

10.6.5.1. The preferred escape maneuver from a diving delivery is the turning maneuver (level turn). After releasing the weapons, execute a 5 G pull to the horizon to an altitude at or above the MSA, then execute a 5 G level to slightly climbing turn through a minimum of 60 degrees heading change. If recovery altitude is below the MSA, then either adjust release altitude to recover at or above the MSA or execute a climbing safe escape maneuver (CLM).

10.6.5.2. The CLM is less desirable since you will complete the maneuver 30 degree nose-high, at a higher altitude with low airspeed. However, terrain or weapons release may force you into a situation where the CLM is required.

10.6.5.3. Escape and egress maneuvers should be well understood, solidly briefed, and precisely flown IAW squadron standards. There should not be confusion over release altitudes, climb angles, power settings, level-off altitudes and egress heading so that wingmen can successfully fly through lead's smoke trail and reestablish a FLIR visual without the help of lead's strobe light (as in a combat environment).

10.6.5.4. TFR Use/Safe Escape. You should plan to use AUTO TF as much as possible. Run-in altitudes at higher SCPs in AUTO may increase LOS range to the target and provide full TF protection while using head down displays. The final portion of most attacks or escape maneuvers require out of limit maneuvering (loft, direct pop, CLM, Turning Maneuver (Level Turn). If you roll to beyond TFR global limits in less than 2 seconds, these out of limits maneuvers can be performed in auto TFR without any fly-ups. This technique is safer, easier to perform, and more tactically sound. Recovery maneuvers should be planned as accurately as possible to increase SA about where and how the egress and descent back to low-altitude will occur.

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CHAPTER 11

NIGHT VISION GOGGLE OPERATIONS

11.1. Introduction. This chapter discusses night vision goggle (NVG) operations. It is divided into six sections: Description, Capabilities, General Mission Planning, Operations, Formations, and Limitations.

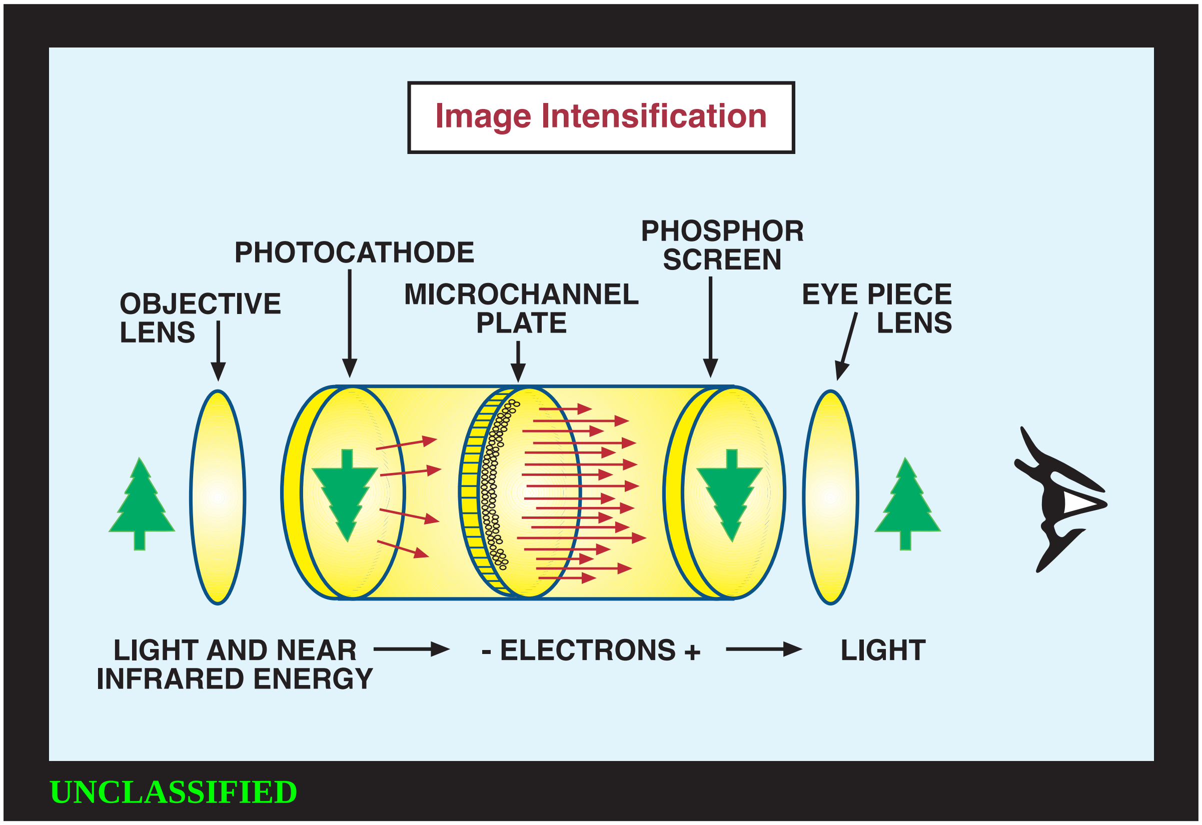
11.2. NVG Description.

11.2.1. Night Vision Goggles. Aircrew NVGs consist of two image intensifier tubes on a fully adjustable, lightweight binocular mount. The image intensifier tubes produce a monochromatic (green) image of the outside world in light conditions too low for normal vision. Forward looking infrared (FLIR) uses the far infrared (IR) area of the electromagnetic spectrum to create an image based on the relative emission of heat by different objects in the scene. NVGs use the red portion of the visible spectrum and near IR energy to produce their own unique visible image of the world. Under adequate conditions of illumination, NVGs can enhance situational awareness (SA), terrain avoidance, navigation, target detection, and identification.

11.2.2. Image Intensifier Tubes. An image intensifier tube is an electronic device which amplifies available ambient light reflected from an object (**Figure 11.1.,** Image Intensification). The reflected light enters the goggles and is focused by the objective lens onto the image intensifier's photocathode, which is receptive to both visible and near-IR radiation. The photons of light striking the photocathode cause a release of electrons, proportionate in number to the amount of light transmitted through the lens. An electrical field which is supplied by the device's power source then accelerates the released electrons away from the photocathode surface. The released photoelectrons are amplified (increased in number) and accelerated (increased in energy) onto a phosphor screen. This impact causes the screen to glow. The phosphor screen emits an amount of light proportional to both the number and velocity of electrons which strike it. Generally, image intensifier technology is expressed in terms of first-, second-, and third-generation systems. Currently the Air Force uses third-generation intensifiers.

11.2.2.1. Third-Generation Intensifiers. Preferred NVGs for the combat air forces (CAF) incorporate third-generation intensifier tube technology. There are two major changes between second-generation and third-generation tubes. An improved photocathode is used and a metal oxide film is applied to the micro-channel plate (MCP). Using an improved photocathode results in third-generation tubes being far more sensitive in the region where near-IR radiation from the night sky is plentiful (**Figure 11.2.**, Comparison of the Human Eye and Third-Generation NVGs). Adding a metal oxide film to the MCP in third-generation tubes greatly extends their service life over that of second-generation tubes. It must be noted that the quality of the image itself can vary slightly between different sets of goggles because of the difficulty in consistently manufacturing third-generation tubes. Indeed, only a certain percentage of the tubes produced meet the specifications established for third-generation intensifier tube performance. The third-generation NVG hardware is the Type 1, direct view, Aviator's Night Vision Imaging System (ANVIS)-9/F-4949 NVGs. Direct view goggles present the image directly from the image intensifier tube to the pilot's eyes. In addition, third-generation NVGs use a minus blue filter, also called a red spectral filter, to limit their response in the lower part of the NVG spectrum.

Figure 11.1. Image Intensification.

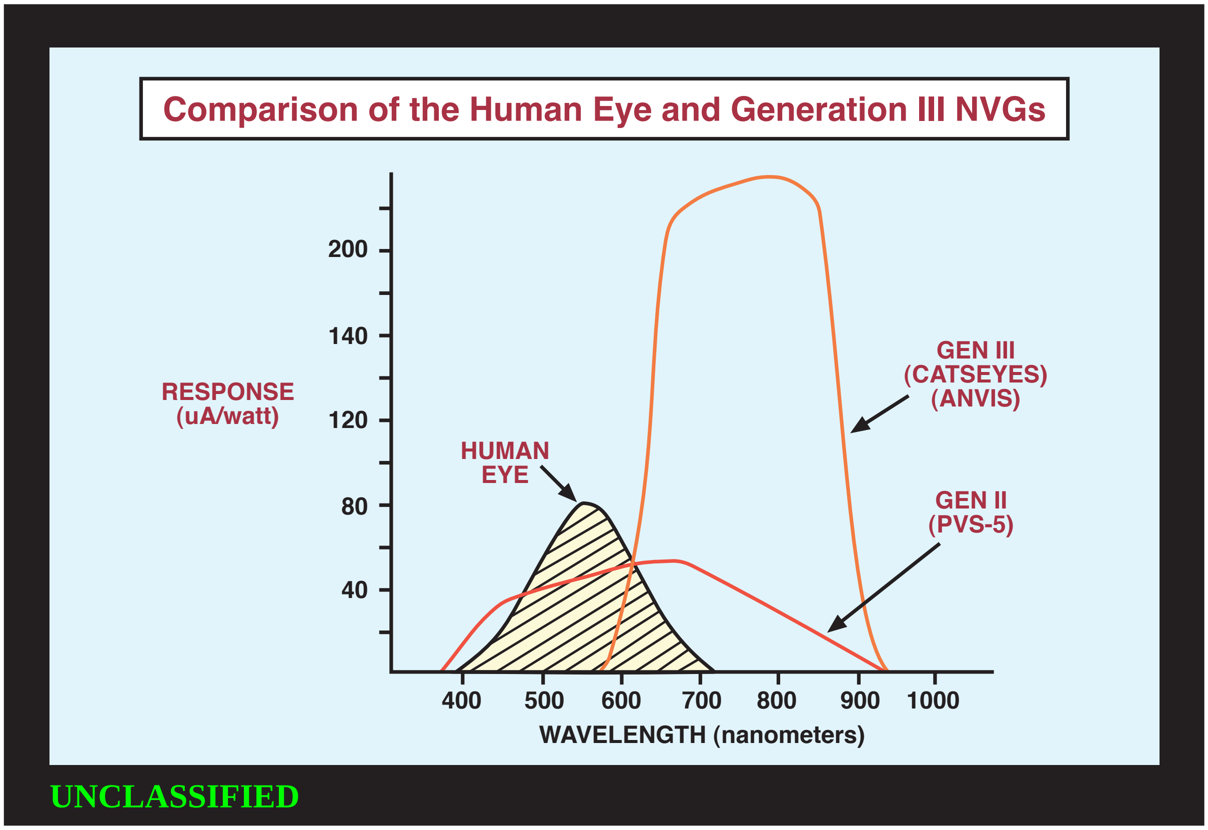


11.2.2.2. ANVIS-9 NVG. The Air Force uses the ANVIS-9 NVG featuring a redesigned MCP which improves the resolution of the goggle from approximately 20/45 to 20/30. The latest versions of the ANVIS-9 have visual acuities as good as 20/25, and come with modified “leaky green” filters which makes them compatible with the F-16 Block 40/42 holographic head-up display (HUD) (**Figure 11.3.**, ANVIS-9 NVGs).

11.2.3. Support Equipment. NVGs have no built-in test (BIT) provisions to determine their serviceability. The only means of determining whether they are performing adequately is through a visual check. Visual checks are accomplished by using an eye test lane, or a Hoffman ANV-20/20 NVD Infinity Focus System.

11.2.3.1. Eye Lane. An eye lane is a corridor, room, or facility approximately 25 feet long that can be relatively sealed from external light. This allows aircrews to focus their NVGs under controlled conditions prior to flight. A resolution chart is placed at one end of the eye lane to determine goggle performance. In order to obtain valid results, the chart must be viewed from exactly 20 feet. A light source is placed in the eye lane 10 feet from the resolution chart off to one side reflecting across the width of the eye lane. Aircrews don their NVGs, look down the eye lane, and focus their goggles on the resolution chart. After using an eye lane, aircrews must re-adjust their NVG focus from 20 feet to infinity.

Figure 11.2. Comparison of the Human Eye and Generation III NVGs.

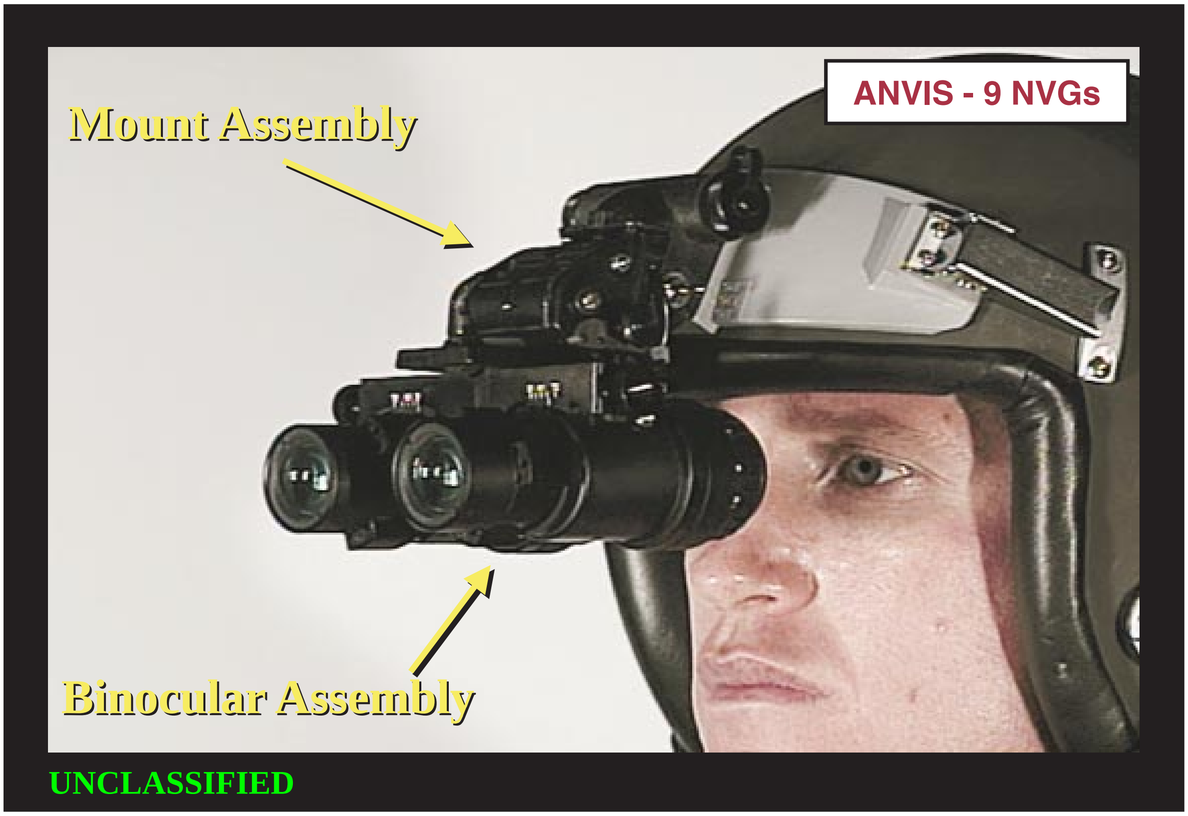


11.2.3.2. Hoffman ANV-20/20 NVD Infinity Focus System. The Hoffman ANV-20/20 tester is the preferred method for aircrews to focus their NVGs prior to flight. Each aircrew dons their NVGs, looks into the test equipment window, and focuses the goggles to infinity on the reticle inside. This deployable tester eliminates the need for a dedicated blacked out room and has the added benefit of allowing the aircrew to focus their NVGs to infinity.

11.2.3.3. Expendable Supplies. Either 1.5V lithium or alkaline batteries power NVGs. Battery life varies, batteries should be changed after about 10 hours of use. Extra batteries should be carried in flight per mission requirements. In addition, NVGs used in aircraft not modified with NVG-compatible lighting require chemical light sticks, Glendale-green plastic film (or an equivalent filter material), black electrical tape and/or Velcro, and potentially other filters designed to make the cockpit compatible for NVG operations. Chemical light stick performance varies from lot to lot and is affected by age, how much sunlight they have encountered, temperature, and humidity. Extra light sticks should be carried per mission requirements.

11.2.4. Aircraft Lighting. Conventional cockpit lighting operates within visible and near-IR wavelengths that may render NVGs virtually unusable even when turned down to the lowest light intensity. This is due to the automatic gain control feature of the NVG. In addition, an incompatible light does not have to be within the NVG field of view (FOV) for it to effect NVG Gain and performance due to the reflection of light off the canopy and other cockpit components. Light bulbs and other light sources in the cockpit must be coated or treated in some way to block the emission of near-IR energy in order to make them NVG-compatible.

Figure 11.3. ANVIS-9 NVGs.



11.2.4.1. Unmodified Cockpit, Option 1. There are two unmodified internal cockpit lighting schemes currently in use. One lighting scheme uses chemical light sticks, Glendale-green plastic film, and black tape. Prior to each night mission, pilots must cover any lighted panels and displays with the Glendale-green equivalent filters, ensure that there are no light leaks and the film is taped securely in place. Prior to in-flight NVG operation, the green chemical sticks are activated and cockpit lighting is turned off.

11.2.4.2. Unmodified Cockpit, Option 2. Another lighting scheme is the Light-Emitting Diode (LED) modification. This modification, commonly called the “Christmas Tree” mod, is pre-wired by life support and requires minimal cockpit setup by the pilot. When ready for NVG operations, the pilot turns off conventional cockpit lighting and activates the LED-modified lighting.

11.2.4.3. Compatible Lighting. Compatible cockpit lighting allows aircrews to see cockpit instruments while not affecting NVG performance. An added benefit of night vision imaging system (NVIS)-compatible cockpit lighting is its improved survivability against enemy personnel equipped with NVGs.

11.2.5. External Lighting. Conventional external lighting from one's own aircraft or other aircraft in formation can degrade NVG performance because of the automatic-gain-control feature of the goggles. Compatible visible and covert/IR external lighting may be installed on aircraft allowing aircrews to fly tactical formations while limiting the possibility of visual detection only to adversaries equipped with NVGs. Fully NVIS-modified aircraft use programmable covert/IR strobes in conjunction with NVGs which greatly enhance SA in multi-ship formations and packages while still minimizing the chances of enemy visual detection (**Figure 11.4.**, Standard Switches).

Figure 11.4. Standard Switches.

Standard Switches

• NORM	OFF	FLSH	BRT	BRT	N/A	“BRT FLASH”
• NORM	OFF	STDY	BRT	BRT	N/A	“BRT STEADY”
• NORM	OFF	STDY	DIM	DIM	N/A	“DIM STEADY”
• NORM	OFF	FLSH	DIM	DIM	N/A	“DIM FLASH”
• NORM	OFF	N/A	OFF	DIM	12:00	“CLOAK”
• NORM	OFF	N/A	OFF	OFF	12:00	“DARK CLOAK”
• NORM	OFF	FLSH	BRT	BRT	N/A	“CHRISTMAS-TREE”
• OFF	N/A	N/A	N/A	N/A	N/A	“UNPLUG”

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11.3. NVG Capabilities. Just like with the unaided eye in daylight, NVGs see line of sight (LOS) to the horizon. Additionally, NVGs sense near-IR energy allowing detection of engine heat, missile plumes, muzzle flashes, etc., which is not seen by the unaided eye. Typically, NVGs allow pilots to see non-compatible aircraft lighting at more than 50 NM, lighted objects beyond 10 NM, and a lit cigarette at about 5 NM. The most significant benefits provided by using NVGs are an increase in aircrew SA, a corresponding increase in safety, and a potential decrease in the risk of fratricide. When flying at night without NVGs, pilots must use a variety of non-visual techniques to accomplish tasks they normally accomplish visually during daylight. These techniques include dependence on air-to-air and terrain following radars (TFR), FLIR pods, A/A tactical air navigation (TACAN), trail formations, flying minimum safe altitudes (MSA), using separate altitude blocks, etc. By using NVGs, pilots are able to perform many of their tasks visually instead of conventional night techniques. Aircraft not equipped with targeting pods (TGP), FLIRs, etc., can operate more effectively at night using NVGs. Advantages can be broken down into seven main categories: cooperation with other thermal imaging devices, visual formation/escort, visual navigation and terrain avoidance, maneuverability, visual identification (VID), threat detection/

survivability, and covert close air support (CAS) operations, all of which allow enhanced nighttime tactics.

11.3.1. Cooperation with Thermal Imaging Devices. NVGs and FLIR thermal imaging devices are complimentary sensors and can aid mission accomplishment through sensor integration. FLIR technology is based on the fact that all objects warmer than absolute zero emit heat. FLIR can discriminate between objects with a temperature of less than 1-degree difference or of the same temperature if they emit heat at different rates (the rate of emission depends upon composition of individual objects). FLIR sensors detect differences in the thermal properties of these materials and create an image on either a HUD or head-down display (HDD). This process called thermal imaging, results in a gray monochromatic image for the aircrew. FLIRs allow detection, recognition, identification, and classification of targets, scenes, or activities that would otherwise be concealed by darkness. **Table 11.1.**, NVG/FLIR Comparison**,** and **Figure 11.5.**, Comparison of NVG and FLIR Technology, shows comparison of NVG and FLIR technology.

Table 11.1. NVG/FLIR Comparison.

NVG	FLIR
Uses Reflective Energy	—
Visible Light and Near IR	Uses Emitted Energy
Mid or Far IR	—
Images Reflective Contrast	Images Thermal Contrast
Requires Some Illumination	Totally Independent of Light
Penetrates Moisture More Effectively	Penetrates Smoke and Haze
Attenuated by Smoke, Haze, and Dust	Attenuated by Moisture (Humidity)
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11.3.2. Visual Formation/Escort. In combat, aircraft are normally flown “lights out” to avoid visual detection by enemy A/A and surface-to-air threats. When lights out, aircrews must use other than visual means to monitor and deconflict with other aircraft in the flight or package. NVGs allow aircrews to fly visual tactical formations and deconflict with each other. Visual formations reduce electronic emissions and increase mutual support. Strike packages can be compressed, reducing time required over the objective and exposure to the threat. Aircraft escorting strike, airdrop, or combat search and rescue (CSAR) packages can do so visually, increasing mutual support and simplifying deconfliction.

11.3.3. Visual Navigation and Terrain Avoidance. NVGs improve SA by allowing pilots to see hazards like rising terrain on either side of the route. In addition, NVGs allow pilots not equipped with low-altitude navigation and targeting infrared night (LANTIRN) systems to visually navigate and avoid terrain at low altitude when required to avoid threats, weather, etc. Even when low altitude flight is not required, NVGs allow aircrews to augment electronic navigation systems by visually navigating at medium altitudes.

Figure 11.5. Comparison of NVG and FLIR Technology.

Comparison of NVG and FLIR Technology

• Uses Reflected Energy (Visible Light and Near IR)	• Uses Emitted Energy (Mid or Far IR)
• Images Reflective Contrast	• Images Thermal Contrast
• Requires At Least Some Illumination	• Totally Independent of Light
• Penetrates Moisture More Effectively	• Penetrates Smoke and Haze
• Attenuated By Smoke, Haze, and Dust	• Attenuated By Moisture (Humidity)

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11.3.4. Maneuverability. Due to fewer visual cues and lower SA at night, pilots generally maneuver their aircraft less aggressively than during daylight. With NVGs, pilots can maneuver more aggressively. This increased maneuverability gives a distinct advantage to fighters attacking or defending against enemy aircraft and increases probability of survival while defending against surface-to-air threats. In addition, aircraft attacking surface targets can employ more attack profiles.

11.3.5. Visual Identification. At night, enemy aircraft will most likely extinguish all exterior lights and may employ emission control (EMCON) tactics under airborne or ground-controlled intercept (GCI) direction. Normal unaided night vision does not permit aircrews to visually acquire or identify such aircraft. NVGs allow pilots to visually scan for other aircraft and are particularly capable of acquiring aircraft equipped with unmodified interior/cockpit lighting. Once an aircraft is seen, NVGs can be used for visual identification (VID), if required.

11.3.6. Threat Detection/Survivability. Operations in DESERT STORM proved NVGs viable for the detection of surface-to-air missiles (SAM) and antiaircraft artillery (AAA). NVGs are also effective in visually detecting enemy aircraft and air-to-air missiles (AAM) in flight. The ability to see at night improves aircraft survivability by increasing a pilot's ability to detect, avoid, and defeat threats.

11.3.7. Covert Close Air Support Operations. Non-NVG units performing CAS require illumination flares to light up the battlefield in order to acquire and engage enemy targets. However, visual-band flares degrade friendly ground troop NVGs and highlight friendly positions to the enemy. By using NVGs, pilots can covertly accomplish their missions, thereby reducing the risk to friendly ground forces.

11.4. NVG Planning Considerations. Mission planning begins by determining expected illumination conditions. Light level planning software programs, such as USAF Nitelite, are used to identify expected light levels. These programs produce sunrise, sunset, moonrise, moonset, moon elevation, and a millilux light level in lumens. MAJCOMs define 2.2 millilux as high illumination regardless of the moon elevation. A general rule of thumb is that 25 percent moon illumination with greater than 30 degrees elevation produces high illumination. Also, just like flying into the sun, elevation is a factor when attempting to ingress or egress into the moon azimuth. Weather has an unpredictable effect on illumination as cloud cover lowers the illumination conditions by an undetermined amount. Pilots should always have a low illumination contingency option.

11.4.1. Environmental Conditions. Mission planning must consider environmental conditions and their impact on night vision devices. Additionally, planning should include spot locations (azimuth and elevation) of the sun and moon for critical stages of the mission, such as engaging the target/objective. Predicted illumination levels should be calculated with the aid of weather personnel and mission tactics planned accordingly.

11.4.2. NVG Performance Considerations. The following are environmental conditions that affect NVG performance and must be understood to safely conduct NVG operations.

11.4.2.1. Luminance, Illumination, Radiance, and Albedo. The two most common terms used when discussing light as it pertains to NVGs are luminance and radiance. Luminance and radiance refer to reflected or emitted light from an object or scene. Illuminance and irradiation refer to the electromagnetic energy striking the object or scene. An example of luminance is the moonlight which is reflected from objects in a given scene. For a fixed illumination level, the amount of light reflected varies with the reflectivity of the objects. The ratio of luminance (reflected energy) to illumination (energy source) is called albedo, which varies with the composition and condition of the particular object or surface. The albedo, or reflectivity, of objects in a scene vary. This difference allows one to detect an object like a dirt road in a scene. It is important to note that while the ambient light provides the necessary illumination, it is actually the reflected light, or luminance, that NVGs detect from objects and the terrain that allows one to “see.”

11.4.2.2. Weather. Any condition of the atmosphere which absorbs, scatters, or refracts the sky's illumination, either before or after it strikes the terrain, will effectively reduce the usable light available to NVGs. Weather and visibility restrictions all serve to alter either illumination, luminance, or both. Recognition of this reduction in the cockpit is sometimes very difficult. The changes are often very subtle reductions in contrast, which are not perceived when viewed through NVGs. The automatic gain control in the intensifier tubes can hide these changes by attempting to provide a constant image in spite of the changing luminance conditions. If cues are perceivable, the aircrew must recognize them and their significance. Common cues to reductions in ambient illumination include loss of celestial and ground lights, loss of the perceivable horizon, reduced contrast, decreased depth perception and distance estimation capability, reduced visual acuity, increased NVG sparkle, scintillation (graininess or “snow” in the scene), and a “halo” effect around light sources. As a general rule, any weather phenomenon which affects vision in daylight will effect NVGs at night. Weather conditions that effect NVG operations include clouds, fog, rain, snow, sand/dust, lightning, and obscurants like haze and smoke.

11.4.3. Illumination Sources. Natural illumination sources include the moon, stars, solar light, and other background illumination. There are also artificial illumination sources such as light from urban areas, fires, automobiles, weapons, searchlights, and flares. In areas without cultural lighting, the moon normally provides the highest percentage of natural illumination at night.

11.4.3.1. Sunset and Sunrise Time. NVG operations can be hampered by zodiacal light in the west for up to 2 hours after sunset. If the mission is flown soon after sunset, profiles should be adjusted to allow west to east operations with zodiacal light at the aircraft's 6 o'clock position. This IR light can be intense immediately following sunset, and can be sufficient to brightly illuminate the objective with the light from behind. If the mission is flown with the objective located in the same relative direction as the zodiacal light, the ambient IR light will reduce NVG gain and the objective may not be detected. Similar preplanning is required beginning about 1 hour prior to sunrise.

11.4.3.2. Moon Phase and Moonrise/Moonset Times. Moon phase and elevation determines how much moonlight will be available, while moonrise/moonset times determine when it will be available. The most important operational aspects of moonrise/moonset times concern times when the moon is low in the sky. Moon angles of less than 30 degrees can render the NVGs ineffective when looking in the direction of the low moon. The moon moves across the sky at approximately 15 degrees per hour. This means it will be a factor for 2 hours after moonrise and for 2 hours before moonset.

11.4.3.3. Cultural Effects. Any common light source is visible in NVGs. Flashlights can be seen out to 25 NM, while cigarettes can be seen out to 5 NM in low ambient lighting conditions. Campfires are IR beacons, which are brilliant on NVGs but can be difficult to see with the naked eye. Red lights on transmission towers are highly visible.

11.4.4. Terrain. Due to changes in climate and lunar cycle, a given terrain scene may look radically different on consecutive nights. Successful NVG operations require an understanding of various terrain characteristics along with the effects of weather and lunar cycles on NVG performance. Terrain features with distinct characteristics when viewed through NVGs include roads, bodies of water, open fields, deserts, forests, snow, and mountains.

11.4.4.1. Featureless Terrain. It is difficult to determine altitude when flying with NVGs over areas of little contrast such as snow fields, water, desert, etc. NVGs by themselves may not give adequate awareness of height above the ground, and other devices such as radar altimeter, FLIR, or TFR, may be required to conduct safe low-level operations.

11.4.4.2. Shadows and Obstructions. Terrain and other obstacles concealed in the shadows of higher terrain or cloud cover are difficult to see while conducting NVG operations at low altitude. Unlit obstructions like electric power lines, towers, poles, antennas, and dead trees, are particularly hazardous, as they may not be detected.

11.4.5. High Illumination Conditions.

11.4.5.1. Employment. High illumination allows pilots to identify turn points and targets, especially if they have vertical development and/or background contrast. Medium- and low-altitude attacks using visual reference points are similar to day missions.

11.4.5.2. Lunar Planning. Routes into low moon angles (less than 30 degrees elevation) or the solar glow of the rising and/or setting sun (within 1 hour of sunrise/sunset) require operating at MSAs or individual comfort level, whichever is higher. Attack axis should be planned at least 90 degrees away from a low moon or solar glow. With a near vertical moon (70 to 90 degrees elevation), terrain features may not be readily apparent. This featureless terrain may cause a flight hazard.

11.4.6. Low Illumination Conditions.

11.4.6.1. Preparation and Planning. Low illumination planning must include all considerations for flying at night with no NVGs. Route planning and attacks must be more benign with radar updates available. Low-altitude fly-ups should be planned with a maximum climb angle of 20 degrees (with no expectation of visually acquiring the target unless it is culturally lit) and to limit afterburner use. Medium- and high-altitude missions require the use of on-board sensors (radar, TGP, FLIR) and an accurate inertial navigation system (INS) or global positioning system (GPS). Planned delivery options should include either system or visual deliveries using continuously computed release point (CCRP), continuously computed impact point (CCIP), or dive toss (DTOS) against culturally lit targets.

11.4.6.2. Increasing Illumination. Low environmental illumination may require artificial illumination to enable mission accomplishment. Placement of visual-band illumination flares in relation to targets or other mission objectives is critical, as these flares can gain down, or interfere with, the aircrew's NVGs. Covert/IR illumination flares allow aircrews to use NVGs on dark nights without degrading friendly ground troop NVGs, exposing their positions, or exposing the position of the target and objective.

11.5. NVG Operations.

11.5.1. NVG Preflight and Adjustment . Extra time after the briefing must be allowed to accomplish the NVG preflight check. Flight testing and operational flying experience has shown this check to be one of the most important steps for a safe NVG flight. The importance of proper goggle alignment, focus, and use of the NVG test lane cannot be over-emphasized. Common malfunctions encountered during pre-flight of NVGs include battery problems, interpupillary distance adjustment problems, one tube not focusing, and light intensifying element damage which results in large “spots” obstructing the crew member's vision. If any of these malfunctions are encountered, another set of NVGs should be obtained from Life Support. Battery failure is a common malfunction that manifests itself differently depending on the type of batteries used. For example, AA penlight batteries tend to fade slowly, causing the viewed image to gradually darken, while lithium batteries tend to fail more suddenly and give less warning of impending failure.

11.5.2. Ground Operations.

11.5.2.1. Post-Engine Start. After engine start, pilots must ensure all external and internal lights are operational. For unmodified external and internal lighting configurations, *ALL* lights must be operable and *ALL* Velcro must be properly positioned. As a technique, do not setup the cockpit with chemsticks, Glendale-green, etc., until sure the aircraft if flight worthy and a spare jet is not required.

11.5.2.2. End-of-Runway. Once in end of runway (EOR) (last chance), don the NVGs and perform a leak check and NVG focus, as required. The leak check is accomplished by scanning the cockpit for any non-compatible light (leaks) and fixing them as required.

11.5.2.3. Cockpit Organization. Cockpit organization is essential for safe and effective mission employment. After NVG focus, stow NVGs and adjust cockpit lighting to as low as practical for takeoff. Pilots should stow NVGs in a convenient place for easy access when airborne. There is ample room under the armrest to stow the goggles (and goggle case) for takeoff and landing the NVGs can also be retained in the "up and stowed" position for takeoff.

11.5.3. Takeoff/En Route. NVGs will not be used during takeoff or if instrument meteorological conditions (IMC) conditions are anticipated on takeoff.

11.5.3.1. Goggle Altitude. Once established above 1,000 feet AGL minimum, and wings-level in the briefed departure formation (radar-assisted trail), flight leads will direct flight members to "goggle." Wingmen will call "GOGGLED" only after interior lights have been set and the goggles properly focused, if required. Normally even numbers in the flight will goggle first, then the odd numbers.

11.5.3.2. Goggle Lighting. Once the entire flight is goggled, flights will rejoin to the briefed formation and set exterior lights as desired/briefed. At least one flight member must remain "Christmas Tree" until established in approved "lights out" airspace. Exterior lighting settings will vary depending on the exterior lighting modification and unit standards.

11.5.3.3. Goggle Reorientation. Once established in the operating airspace, the flight should accomplish a "G-maneuver" to make sure all light sticks and pen lights remain in the stowed position. Additionally, as a technique, perform a "30-Up and 30-Down" maneuver to re-familiarize flight members to horizon orientation.

11.5.4. Air Refueling. NVGs will not be worn for air refueling operations. De-goggle NLT the pre-contact position. NVGs may be stowed or worn in the up position for air refueling operations. Goggle when refueling is complete and established on the tanker's wing.

11.5.5. Recovery.

11.5.5.1. Battle Damage Checks. Battle damage checks will be accomplished IAW local standards or when damage is suspected. Checks will be done "comm in." Wingmen will join to NVG close and set the leader's lights as desired, and perform a battle damage check with a cross-under similar to daytime. A lead change will be initiated on the radio and then lead will reset lights. After lead has checked the wingman, another lead swap will occur and both aircraft lights will be set as briefed.

11.5.5.2. Prior to Landing. Flights will "de-goggle" at least 5 minutes prior to landing. De-goggle will be directive and comm in, normally, evens first, then odds. Additionally, pilots should de-goggle early if anticipating IMC.

11.5.6. Emergencies.

11.5.6.1. Primary Hazard. The primary hazard is during ejection and concerns both the NVGs interference with the ACES II seat (pitot tube damage) and injury to the pilot due to wind blast effects on the NVGs. Normally the NVGs will not remain fixed during the ejection.

11.5.6.2. Wind Blast Effects. If the NVGs remain fixed, expect head/neck injuries caused by wind blast. Additional considerations should include parachute and/or riser entanglement increasing injury potential. Attempt to stow the NVGs if ejection is anticipated.

11.5.7. Abnormal Procedures.

11.5.7.1. Loss of Sight. There will be instances of the wingman/element lead going blind due to limited NVG FOV. Proper NVG scanning helps prevent this condition. When a flight member goes blind, the pilot transmits “Call Sign, BLIND, Altitude (example: “SPAWN 4, BLIND, 9.6”).” The altitude call allows the other flight members to immediately deconflict flight paths by altitude. If the flight lead is visual and can tell the wingman's aspect, the leader gives the clock position and estimated range from the wingman. If the flight lead is unsure of the wingman's aspect, the leader gives own position as bearing and range from the wingman. When the wingman regains a visual, maneuver aggressively to regain formation position. If the wingman does not regain a visual, one of four pre-briefed light signals can be used to aid in establishing visual contact: chaff, afterburner, strobe, and flares. Wingman requests the appropriate light signal as follows: “Call Sign, FLASH CHAFF/BURNER/STROBES,” or “Call Sign, FLARE.” The tactical situation and proximity of enemy forces temper all light signal usage.

11.5.8. Battery Replacement. Pilots will initially use the right battery (switch in the UP position). Upon illumination of the battery light, switch to the left battery (switch down). For other suspected malfunctions, switch to left battery. Consider changing the lead or informing the rest of the flight during battery replacement due to reduced SA while de-goggled.

11.5.9. NVG Failure. Deconfliction and maintaining spatial orientation is the primary consideration. Correcting the NVG failure is secondary. Accomplish the following:

- Transition to instruments and execute “Lost Wingman” procedures.
- Terminate or knock-it-off as appropriate. Direct “Christmas Tree.”
- Enter and maintain correct block with adversaries or other fighters present.
- With deconfliction assured, attempt to identify and solve the problem.
- If failure is hard, proceed with non-NVG plan.

11.5.10. NORDO Plan. Go “Christmas Tree” and proceed with primary/briefed NORDO plan.

11.6. Formations.

11.6.1. Formation Considerations. The 40-degree NVG FOV requires most formations to be modified and several formation considerations are necessary.

11.6.2. Wingman Priority. The wingman's primary non-critical task is to maintain formation. As NVG experience increases, wingmen will become more adept at working avionics while flying formation.

11.6.3. Performance Characteristics. All flight members must be intimately familiar with the operation and performance characteristics of the external light scheme. Wingmen must have the option to adjust the flight leads external light settings. More than one adjustment may be required as illumination conditions change during flight. If the night package is NVIS-modified, the optimum external light setup will be dictated by tactical and environmental considerations. If covert lighting is not available, adjust the normal exterior lights to the lowest practical intensity that allows formation station keeping.

11.6.4. Tactical Turns. When maneuvering tactical formations at night, all flight members should generally strive for level turns with Mil power and G loading to maintain airspeed. Flight members will have difficulty accomplishing other tasks, such as radio changes, until turns are completed. Altitude stacks of any magnitude are difficult to maintain due to the limited FOV of the NVGs. Flight members can stack above or below the leader to maintain visual when cultural lights or stars become a problem. As NVG proficiency increases, all formation parameters are easier to maintain. Due to the limited NVG FOV, night line abreast (NLAB) formations require comm-in turns (with headings) to ensure positive flight path deconfliction and adherence to briefed airspeed.

11.6.5. NVG Close. Similar to Fingertip, but more than 3 feet of wingtip spacing is maintained to keep entire lead aircraft in NVG FOV (**Figure 11.6.**, NVG Close).

11.6.6. Two-Ship NVG Fluid. Wingman positions 30 to 60 degrees aft of leader's 3/9 line and 1,000 to 6,000 feet out when not turning. Wingman remains fluid to keep leader in NVG LOS during turns and is cleared to cross the leaders 6 o'clock position as required. Wingman are responsible for flight path deconfliction. A/A TACAN can be used for proper spacing. Inside 6,000 feet, individual aircraft lights are discernible and can be used as a visual cue (**Figure 11.7.**, NVG Fluid Formations).

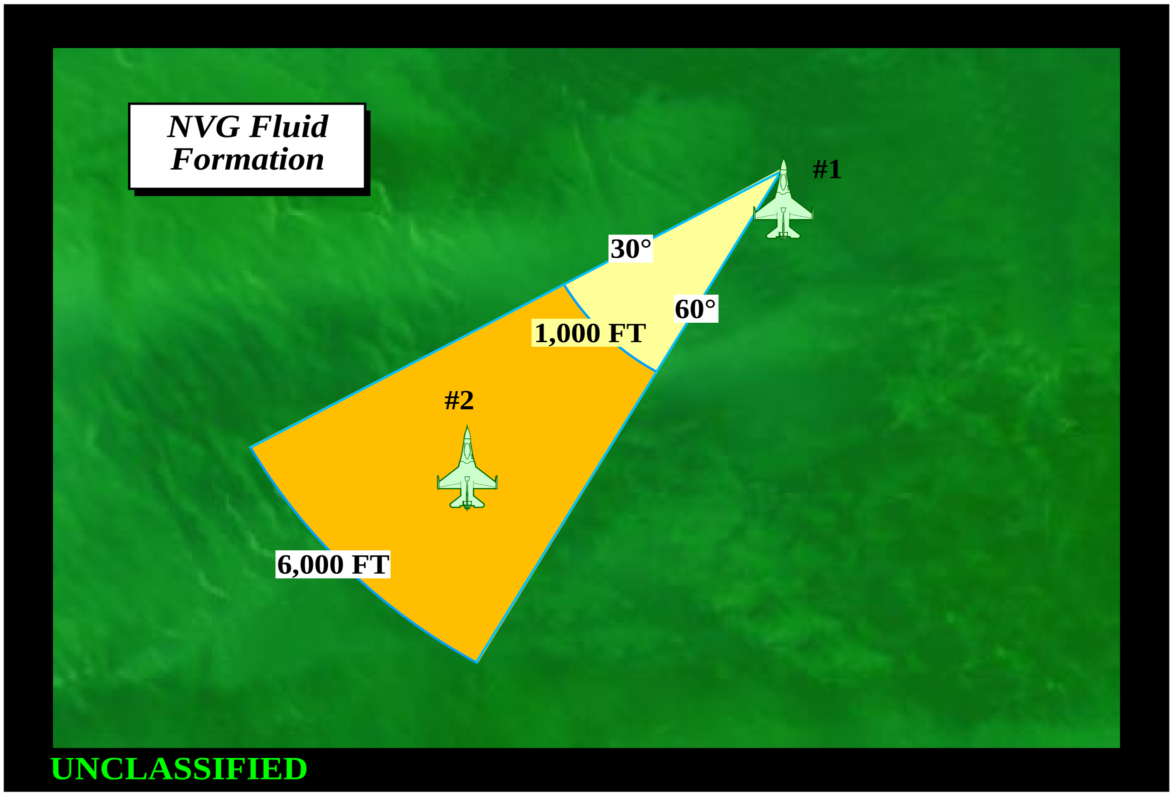
11.6.7. Two-Ship Night Line Abreast. Wingman flies 10 to 45 degrees aft of leader's 3/9 line and 3,000 to 9,000 feet out. The preferred position is to fly as close to 10 degrees aft as possible. This position makes it easier for the flight leader to keep track of the wingman. The outer limit is 9,000 feet, not for the wingman's visual, but for the flight lead to check the wingman without having to search through many stars and/or cultural lights. As task level increases or maneuvering becomes more dynamic, the tendency is to fall back to 30 to 45 degrees aft. When the maneuvering settles down, the wingman should use power, including afterburner if required, and geometry to regain the 10 degrees aft position. Turns are performed similar to daytime LAB formations with comm-in radio calls (**Figure 11.8.,** NVG Night LAB).

Figure 11.6. NVG Close.

11.6.8. NLAB Formation Contracts. Flight lead calls turn direction and roll out heading ±10 degrees, holds pre-briefed airspeed ±20 knots, and calls updates with new parameters if required “Call Sign, 90 LEFT, 240 DEGREES.” Lead uses Mil power and required G to hold airspeed. Wingmen attempt to match lead's turn and flight members on the outside of the turn are responsible for flight path deconfliction. Check turns and wing flashes by the flight lead will be difficult for the wingman to notice. Directive radio calls are the most positive method to initiate a turn. The wingman then starts an immediate Mil power turn to the referenced heading. Lead delays the turn until the wingman flies outside lead's NVG LOS, then lead performs a normal Mil power turn. Check turns and wing flashes by the flight lead will be difficult for the wingman to notice. Directive radio calls are the most positive method to initiate a turn. The wingman then starts an immediate Mil power turn to the referenced heading. Lead delays the turn until the wingman flies outside lead's NVG LOS, then lead performs a normal Mil power turn. With 90 degrees of turn completed, the wingman can transition to a more fluid turn, ensuring altitude deconfliction.

11.6.8.1. NLAB 90-Degree Turn. See **Figure 11.9.**, NVG 90-Degree Turn into the Wingman, for an example. Wingman ensures altitude deconfliction by visually placing the flight lead above or below the horizon (while keeping the horizon in sight) and flies a fluid turn. The position may be widened upon roll out. Radio calls referencing the turn and roll out headings are helpful for the wingman.

Figure 11.7. NVG Fluid Formation.

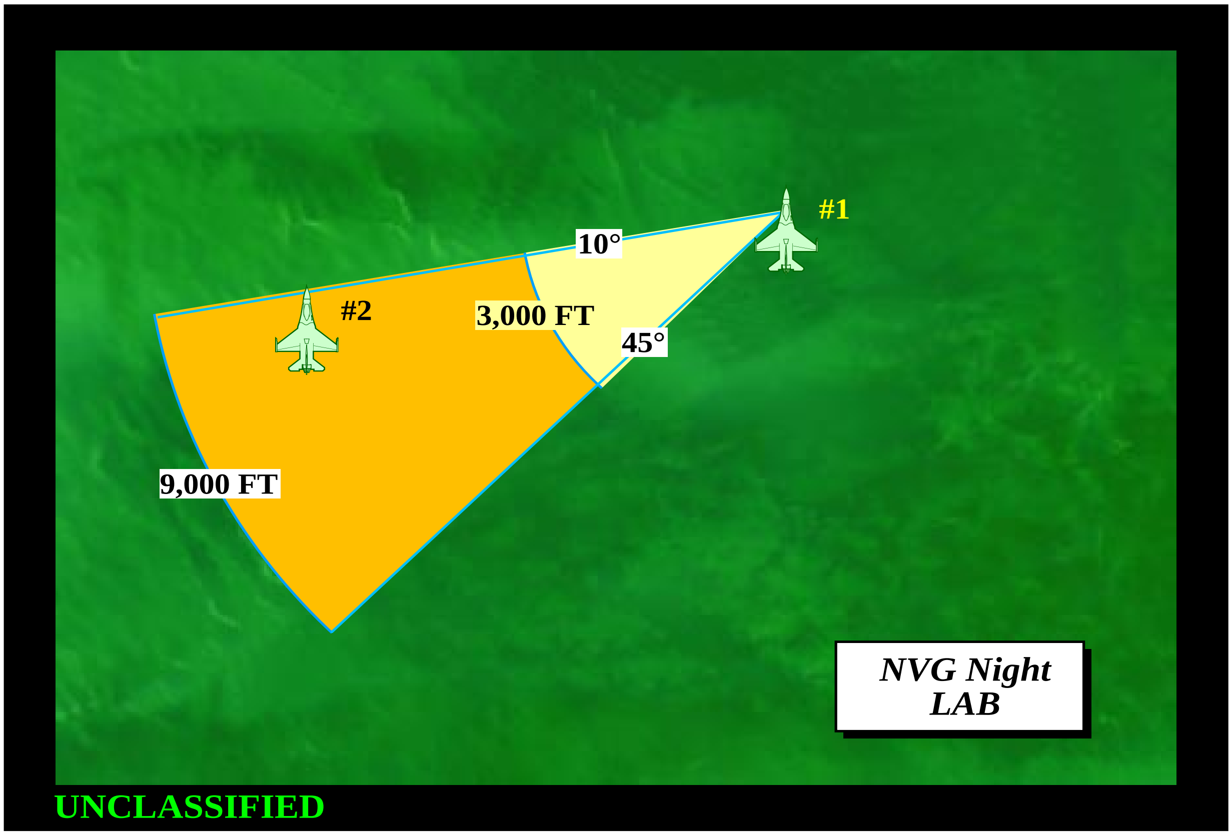


11.6.8.2. NLAB l80-Degree Turns. See **Figure 11.10.**, 180-Degree Turns, for an example. Wingman ensures altitude deconfliction by visually placing the flight lead above or below the horizon (while keeping the horizon in sight) and turns maintaining a fluid position. The position may be widened upon roll out. Radio calls referencing the turn and roll-out headings are useful for the wingman.

11.6.9. Four-Ship NVG Offset Box. Wingmen flies 10 to 45 degrees aft of leads 3/9 line with 3,000 to 6,000 feet separation. The trailing element lead flies 2 to 3 NM in trail of the lead element. The engine light from lead makes it easy for the element to remain visual with the lead element. Since range estimation can be difficult, A/A TACAN should be used between element leads. If A/A TACAN is not available, the radar can be used for station keeping. Wingmen must fly closer than the two-ship NLAB position to ensure flight paths do not conflict with the other element **(Figure 11.11.**, Four-Ship NVG Offset Box).

11.6.10. Four-Ship NVG Offset Box Turn. Each element makes a standard turn (wingmen use a more fluid turn vice daytime tactical turns) with the trailing element delaying approximately 25 to 30 seconds to allow for the 2 to 3 NM spacing behind the lead element (**Figure 11.12.**, Four-Ship NVG Offset Box Turn).

Figure 11.8. NVG Night LAB.



11.6.11. Night Fluid Four. Flight leads fly two-ship night LAB. Wingmen fly 30 to 60 degrees aft of leads 3/9 line with 1,000 to 3,000 feet separation. The formation turns are the same as two-ship NLAB between Number One and Number Three. Both wingmen maintain a tight, fluid position during the turns to prevent conflict with the other element. This formation can be useful for long, straight portions of flight and may be used to maintain position in certain A/A applications such as in the combat air patrol (CAP) or in the commit. However, it is a difficult formation to use for air-to-ground (A/G) attacks **(Figure 11.13.**, Night Fluid Four Formation).

11.6.12. Tactical Lead Changes. The increase in wingman task loading during nighttime employment can require more tactical lead changes. The flight lead's decision to pass the lead to the wingman is dependent on the tactical situation and the wingman's proficiency.

11.6.13. Flight Lead has a Visual on Wingman. The flight lead calls “Call Sign, LEAD LEFT/RIGHT” and expects a corresponding acknowledgment from the affected flight member. This passes the engaged fighter's responsibilities to the wingman and the flight path deconfliction and formation responsibilities to the leader.

11.6.14. Flight Lead is Blind on Wingman. The flight lead calls “Call Sign, BLIND, STANDBY LEAD LEFT/RIGHT”. This call is a request for the wingman to respond with position in relation to lead and be prepared to take the lead when the flight lead regains a visual. When the flight lead regains the visual, the lead will be passed as discussed in **paragraph 11.6.13**

Figure 11.9. NVG 90-Degree Turn into the Wingman.

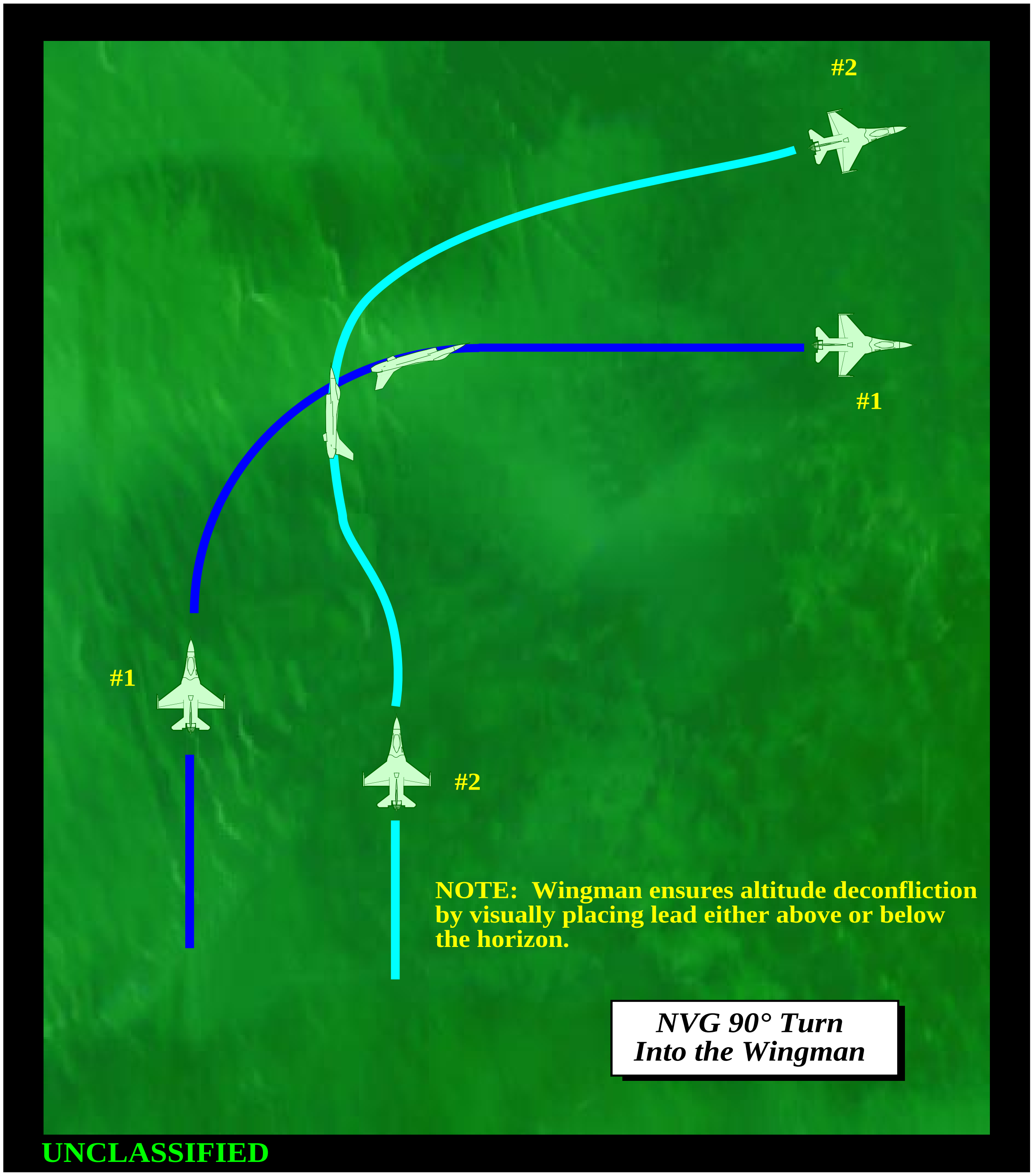


Figure 11.10. 180-Degree Turns.

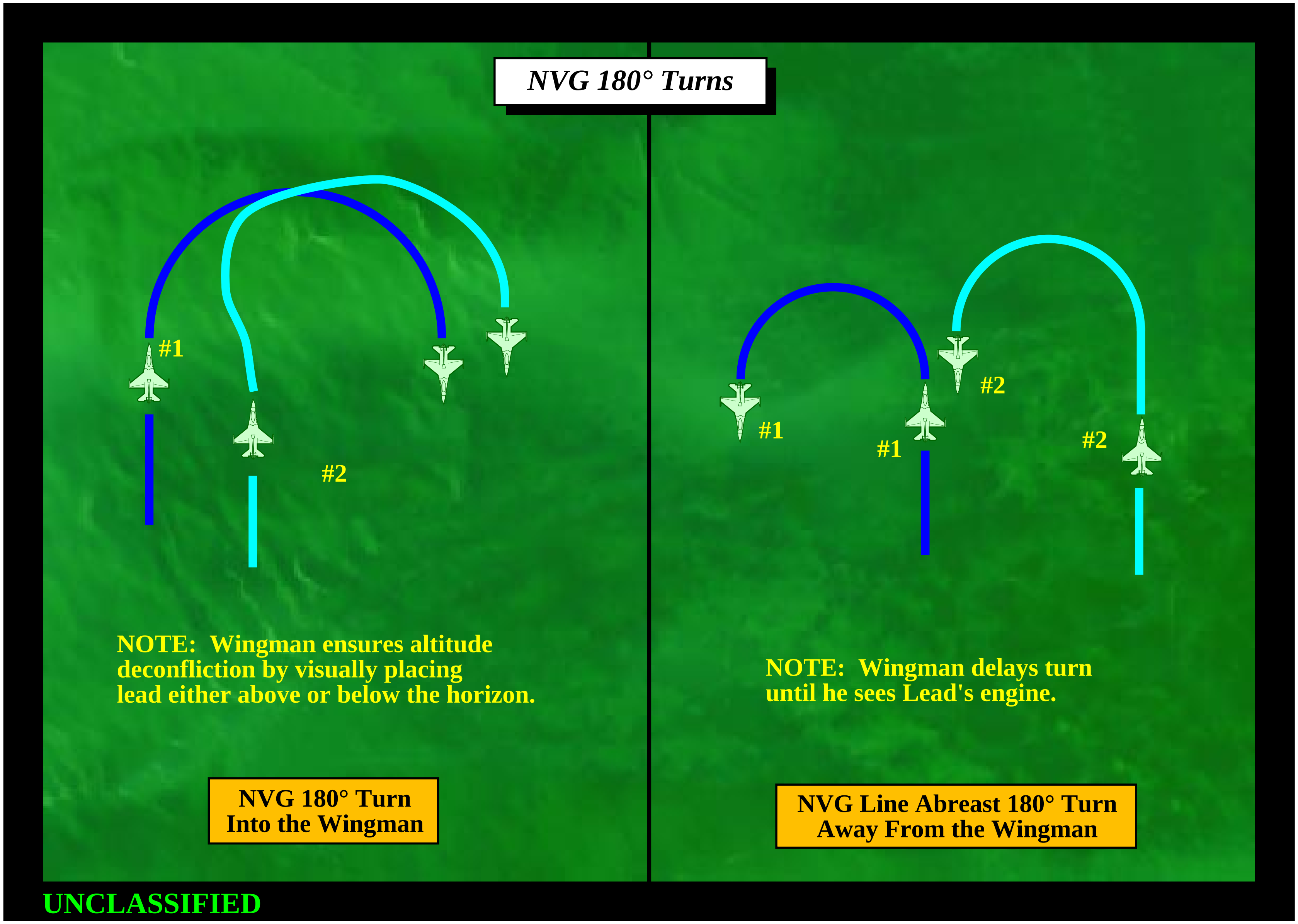
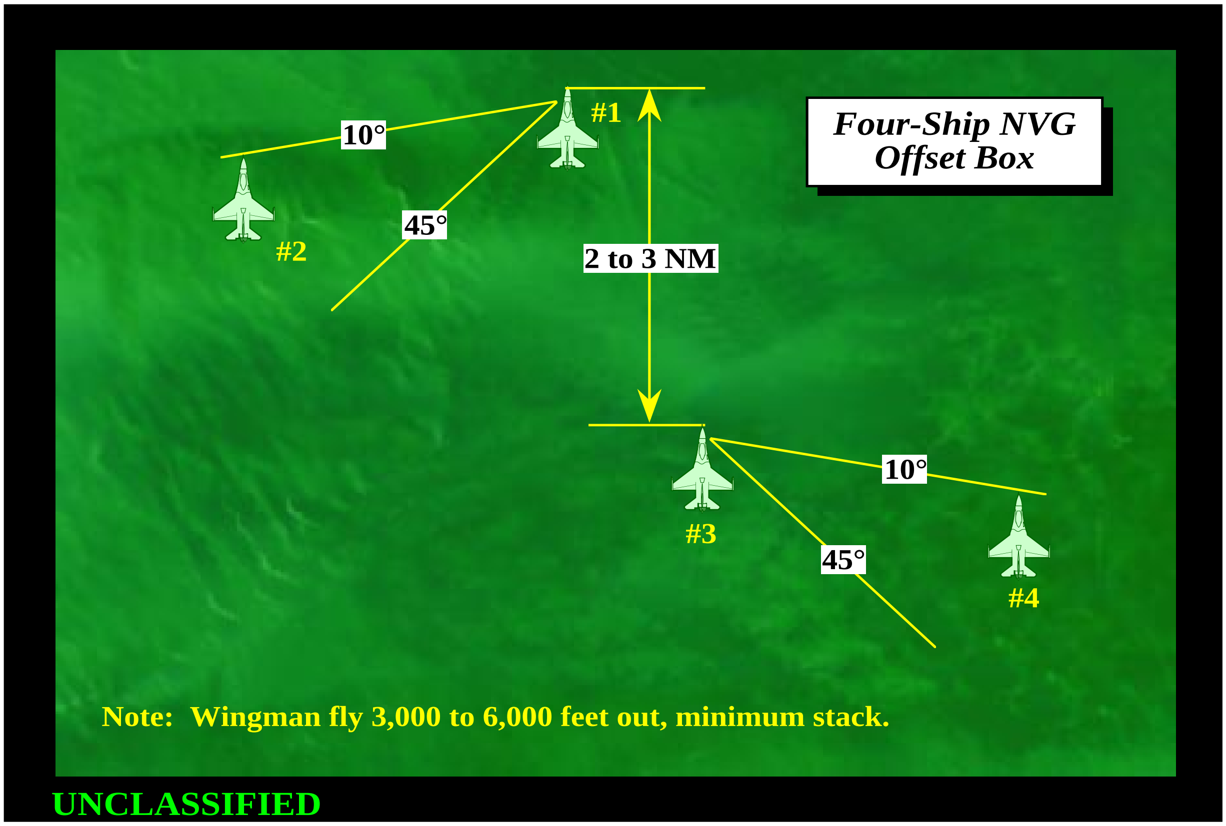


Figure 11.11. Four-Ship NVG Offset Box.



11.7. Night Vision Goggle Limitations. Although NVGs can improve performance at night, they have numerous limitations which aircrews must be familiar with in order to use them safely.

11.7.1. Field of View. FOV refers to the total instantaneous area covered by the NVG image. FOV depends on NVG design and type, and ranges from 30 to 40 degrees for current systems. Regardless of the FOV of any particular system, it is considerably less than the eye's normal FOV of 120 degrees by 80 degrees. This lack of good peripheral vision can influence the onset of misperceptions and illusions.

11.7.2. Windscreen and Canopy Transparency/Transmissivity. Windscreens, canopies, or other transparencies through which the aircrew must look degrade NVG performance. Some transparencies transmit visible wavelengths fairly well, but near-IR wavelengths poorly. Since NVGs use near-IR wavelengths, those transparencies would keep much of that energy from reaching the goggle, thus degrading the image of the outside scene. Just because an NVG has a 20/40 capability in the eye lane does not mean it will give the aircrew a 20/40 capability from the cockpit.

11.7.3. Resolution. Resolution, or visual acuity, refers to the ability of the goggle to present an image that makes clear and distinguishable the separate components of a scene or object. Normal unaided night vision is approximately 20/200. Current NVGs typically have a resolution capability of between 20/25 to 20/40. While not as good as day vision, NVGs represent a significant improvement in night visual acuity.

Figure 11.12. Four-Ship NVG Offset Box Turn.

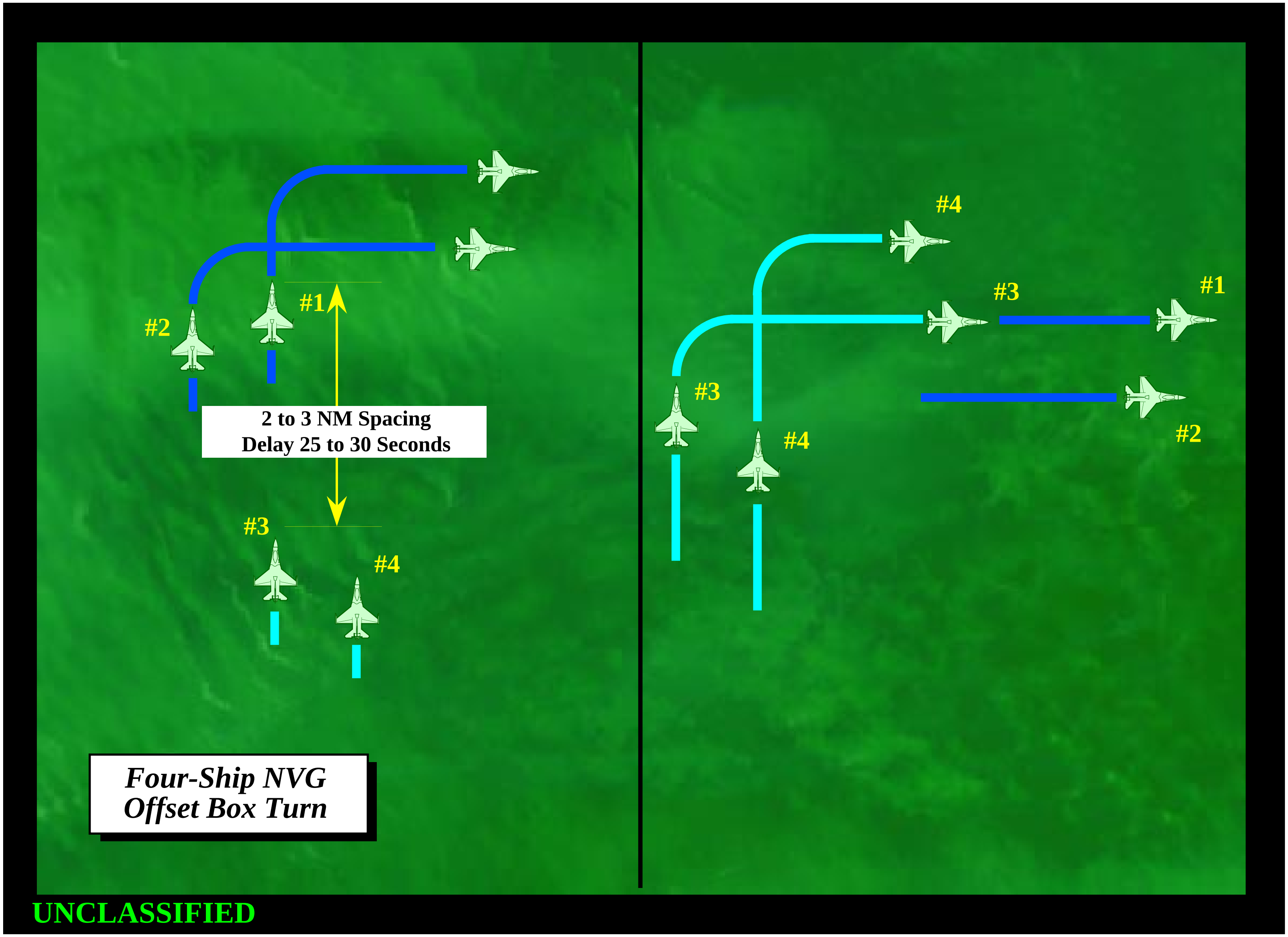
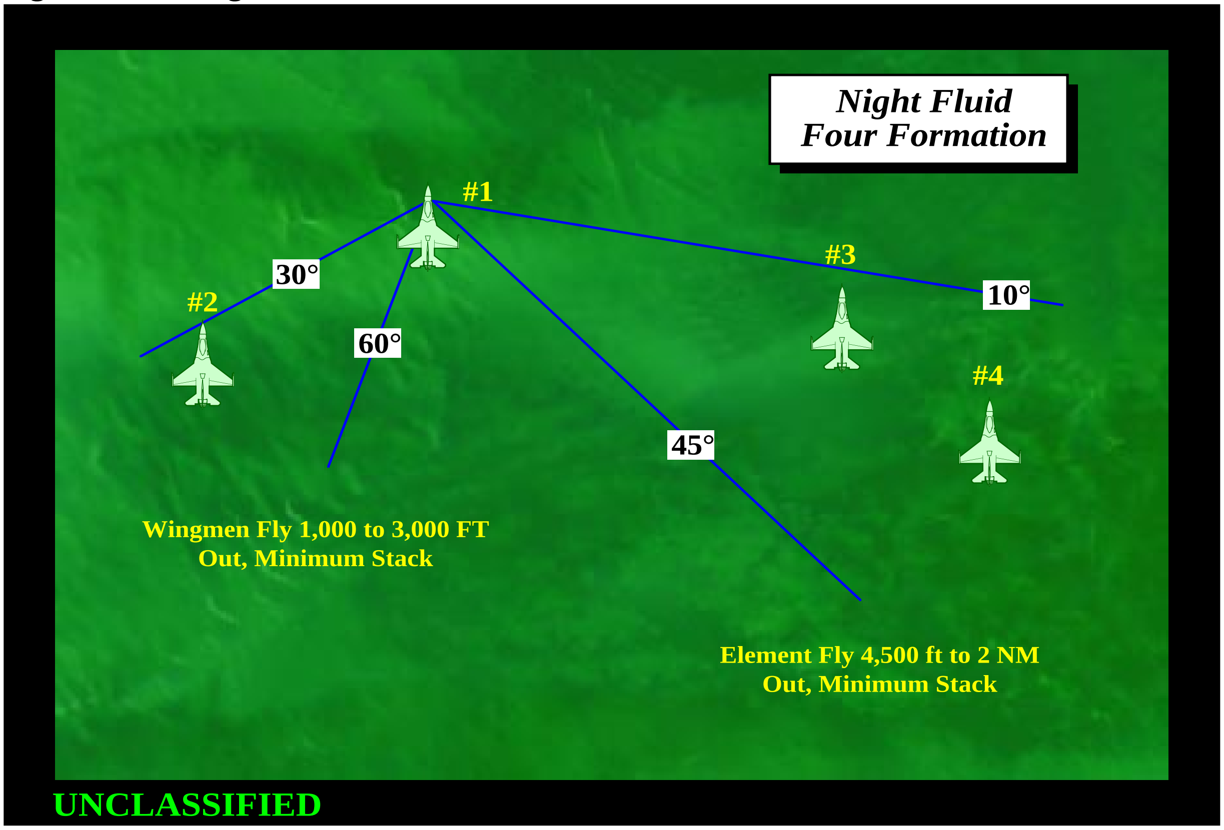


Figure 11.13. Night Fluid Four Formation.



11.7.4. Depth Perception. Depth perception encompasses determining the relative distance of objects in relation to each other. There are two types of depth perception cues; binocular and monocular. Binocular cues are basically a triangulation of retinal points called stereopsis. This provides the 3-dimensional aspect of out vision. With NVGs, stereopsis is still possible, but is limited to distances less than 50 meters. With NVGs, depth perception is judged primarily by using monocular cues. Monocular cues include relative size and height of objects, overlap of objects, convergence of parallel lines, and motion parallax (closer objects within the FOV moving faster than farther objects.). Binocular cues are limited by distance, while monocular cues are limited by degraded acuity and reduced contrast.

11.7.5. Distance Estimation. Distance estimation is altered while using NVGs due to a reduction in visual acuity. The results in unlit objects sometimes appear farther away than they actually are. This is primarily a learned subconscious phenomenon as humans expect objects that are less distinct in detail to be farther away than those which have sharp detail. This can cause problems with overestimating altitudes or distances. The opposite occurs when observing lit objects, which may result in underestimating distances.

11.7.6. Reduced Contrast. Reduced contrast manifests itself primarily as reduced visual acuity since low contrast objects are more difficult to see than those that have a high contrast. A reduction in contrast occurs as the eye is presented a monochromatic image and color contrast cues are lost. Also, a bright light source in the FOV will reduce contrast as the NVG begins to reduce the gain. Because there are individual differences in sensitivity to contrast, there can be differences among aircrews of the same flight with regard to what they can and cannot see.

11.7.7. Degraded Ability to Detect Meteorological Conditions. One of the most dangerous situations that can be experienced with NVGs is flight into undetected meteorological conditions. The inability of the NVGs to see various areas of moisture can lull the aircrew to continue further into IMC to a point where there is virtually no visual information. This can result in a gradual loss of scene detail and place the aircrew in an area of heavy moisture and, in the low-level environment, place the aircrew in a potential conflict with masked terrain. This late detection of IMC decreases the time available for the aircrew to transition from visual flight using NVGs to instrument flight using aircraft instruments, and reduces the time available to execute a route abort from low altitude if required.

11.7.8. Spatial Disorientation. Although NVGs usually improve SA, under certain conditions they can enhance the possibility of spatial disorientation. This is due to the NVGs limited FOV and lack of resolution.

11.7.9. Overconfidence. After initial NVG training, there is a natural tendency for aircrews to become overconfident in their abilities during NVG flight. However, NVGs DO NOT turn night into day. They have very real limitations, and aircrews must exercise caution to avoid becoming complacent.