# HELLFIRE

## Getting the Most from a Lethal Missile System

**by Captain Adam W. Lange**

*At 0100 hours on 17 January 1991, eight AH-64 Apaches from the 101st Airborne Division (Air Assault) depart from a staging airfield in Western Saudi Arabia on a mission code-named "Normandy." The decisive point of the operation is the destruction of two key Iraqi radar sites located about 35 miles apart. Split into two teams of four in order to service both targets at once, both teams conduct a 90-minute, low-altitude, night-vision goggle flight into Western Iraq under strict radio listening silence. At exactly 0238 hours, the Apaches fire a volley of 27 Hellfire missiles, destroying critical targets at each radar site. Four and one-half minutes later, with the first shots of Operation Desert Storm successfully delivered, over one hundred Coalition jets begin streaking up a "blind" Iraqi air corridor approximately 20 miles wide enroute to multiple targets in Baghdad. Mission complete, the Apaches cautiously wheel around to begin their egress home, and the Persian Gulf War is on...*

The mission described above is, by now, known by many to be the real-life, secretive start of Operation Desert Storm. It also provides an excellent example of the capabilities of the Army's Hellfire missile system; an extremely lethal and effective point weapon system capable of precision accuracy and destruction when properly employed. Currently, the Hellfire missile is an exclusively aviation-employed weapon system, launched by Army and Marine Corps aviation units from a variety of helicopter platforms, to include the AH-64A Apache, the AH-1W Super Cobra, the OH-58D Kiowa Warrior, and the Special Operations UH-60 variant. Why discuss an aviation weapon system in this forum, which is fundamentally dedicated to armored ground systems and training? The answer is simple. Ground maneuver commanders take note: the Hellfire missile system is your weapon system, too!

While it is true that the Hellfire missile is utilized by aviation forces conducting aviation missions, it is almost always done so in support of the *ground* maneuver commander's tactical plan. Thus, it is primarily used to achieve a desired effect for the ground maneuver commander at many levels, ranging from battalion/squadron to echelons above corps. In addition, aviation brigades will seldom, if ever, operate entirely independently of their sister units on the ground. Often, attack and armed reconnaissance aircraft are attached or OPCON to battalion- and brigade-sized units as part of an aviation task force. Our present combined arms doctrine supports this point of view, strongly emphasizing the need for close air/ground integration to exploit timely maneuver in all battlefield dimensions, and to allow for the massing of all destructive fires — both surface-to-surface and air-to-surface.[1]

Like any other battlefield weapon system which they employ, all commanders and operation planners, both air and ground, must have a basic understanding of how the system works, its capabilities, and, most importantly, its limitations. This, in turn, will help to ensure proper planning for use of the Hellfire missile as a contributor to the commander's tactical plan. That plan could very well see Hellfire-armed aircraft employed in a wide variety of missions, such as the anti-armor counterattack; in a reserve role, as part of a larger unit's deep fight against selected high value/high payoff targets; as part of a Joint Air Attack Team (JAAT); or in an engagement area in the close battle.

### Missile Data and Specifications

Table 1 outlines some of the basic missile data and specifications of the Hellfire (Anti-Tank Guided Missile or AGM 114) system.

As indicated in Table 1, there are six different production models in the U.S. missile inventory, each with different design features and capabilities. These different models are:

- AGM-114A. This missile is the original design Hellfire missile with basic sub-components and a low-smoke rocket motor. It flies the highest trajectories of the six missile models.
- AGM-114B. This missile has an improved low visibility (ILV) capability; it flies lower trajectories than the AGM-114A, and contains a minimum-smoke rocket motor (less than the AGM-114A). The AGM 114-B contains a Safe and Arm Device (SAD) which provides an electrical and mechanical blockage in the rocket motor firing train, making it approved for U.S. Navy shipboard use by the Marines, as well as being compatible with Army aircraft.

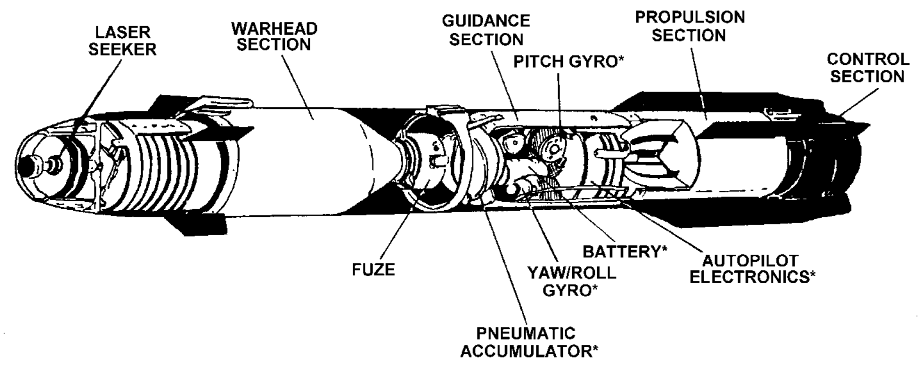

**Figure 1. Hellfire Missile**[5]

- AGM-114C and AGM-114F. These missiles have the same ILV capability as the AGM-114B. They fly the same lower trajectories with the same minimum smoke rocket motor, but do not contain the SAD.

- AGM-114K. This missile has the highest probability of re-acquiring a target if the missile flies into low clouds. It is the only missile produced with an internal guidance algorithm to account for this condition by design. If the missile loses laser lock after initial acquisition, the seeker section will continue to point at the target. Instead of continuing to climb and fly a normal profile, the missile is programmed to turn and point in the same direction as the seeker. This causes the missile to fly down (out of the clouds) toward the target and maximize the probability of re-acquiring the target.

- The AGM-114F and AGM-114K have an additional warhead for improved performance against reactive armor.[2]

*Editor's Note: Martin Marietta Technologies is now building another version, the AGM-114L, for the Longbow Apache system. It is similar to the AGM-114K (Hellfire II) but has a millimeter wave, fire-and-forget guidance system.*

### How the Hellfire Missile System Works

Originally designed for use in the antitank role, the Hellfire missile has also been used successfully to engage other targets as well. Point targets such as bunkers, radars, large antenna arrays and communications equipment, small buildings or towers, and even fast-moving boats can be effectively neutralized or destroyed. If needed, it can even be employed in the air-to-air role against slow-moving or hovering helicopters.

The name "Hellfire" is derived from an acronym for *Heliborne-launched, Fire and Forget*, but the name can be misleading.[3] Fire and forget gives the impression that the missile guides itself to the target autonomously without further input by the air crews after launch. This, however, is a misconception and only partially true. The Hellfire missile is a guided munition, much like the older TOW missile. It requires a coded laser beam to be placed on the target, and the missile will actually follow or "ride" the properly coded beam to the point of impact. Thus, the missile never actually acquires the target in question, but rather acquires the laser beam. The laser designator or "observer," either airborne or ground-mounted, must *always* positively control the missile after it is launched in order to bring it to bear on the target in question.

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|---|---|
| **Weight (each missile):** | 100.9 lbs (108 lbs - L Model) |
| **Length:** | 64 inches (69 in. - L Model) |
| **Diameter:** | 7 inches |
| **Wingspan:** | 12.8 inches |
| **Max. Velocity:** | 950 mph - 475m/sec - 1393 fps (1.4 mach) |
| **Velocity required to Arm:** | 10 Gs (normally achieved 150-300m in front of the aircraft) |
| **Warhead:** | Copper-lined conical shape charge, High Explosive Anti-Tank (HEAT) - explosive force equivalent to 35 mach |
| **Sub-components:** | 5 sections - Seeker; Warhead; Guidance; Propulsion; Control |
| **Launch Motor:** | Solid Fuel (2-3 seconds to motor burnout after launch) |
| **Effective Range:** | 500m minimum range;<br>8000m maximum effective range |
| **Missile Battery Life:** | 46 seconds +/- 2 seconds |
| **Maximum Rate of Fire:** | 1 missile every two seconds |
| **Number of models:** | 6; AGM-114A/B/C/F/K/L |
| **Manufacturer(s):** | Rockwell International Systems Division and Martin Marietta Inc. |

**Table 1. Missile Specifications**

Regardless of specific model, each Hellfire missile has five basic sections or major sub-components that allow it to operate during the sequence from launch to detonation. These sub-components are: the propulsion section, laser seeker, guidance section, control section, and the warhead.

The propulsion section is located between the guidance and control section, near the aft end of the missile. It has a solid fuel propellant that burns approximately 2-3 seconds, depending on the outside air temperature. The purpose of the propulsion section is to generate enough thrust to separate the missile from the launcher, to attain the 10 Gs of thrust necessary for arming the missile, and powering it to the target. The relatively short burn time is more than sufficient to allow the missile to reach its maximum effective range of 8 kilometers. In fact, the missile is capable of destroying targets beyond 8 kilometers, but the overall probability of hit ratio ($P^h$) decreases as distance increases.

Located in the nose of the missile, the laser seeker is programmed from inside the aircraft to receive a specific laser code. When the missile recognizes this code being emitted from a designator and reflected off of the target, it "locks on" to this emission. After lock-on, the seeker then sends this information to the guidance section which directs the missile to the target. After receiving information from the laser seeker, the "brains of the missile," or guidance section, computes steering command data to stabilize the missile and then transmits this data to the control section.

The control section, located at the very aft end of the missile, contains a pneumatic actuation system that converts steering commands into mechanical fin movement. It is this fin movement that

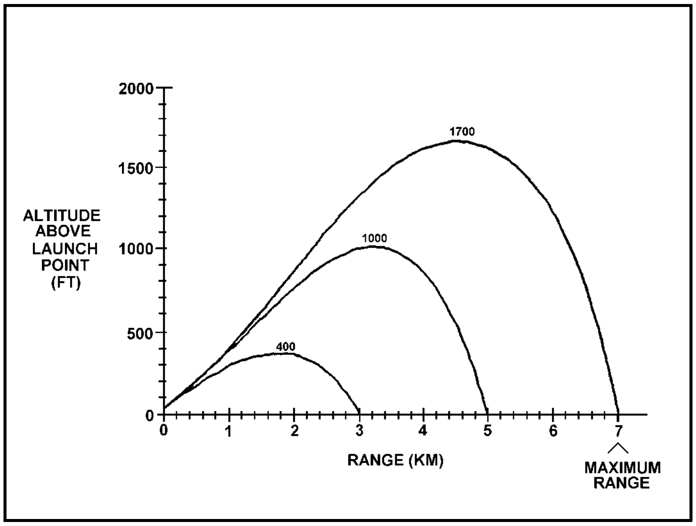

Figure 2. LOBL Trajectories (AGM-114A)[6]

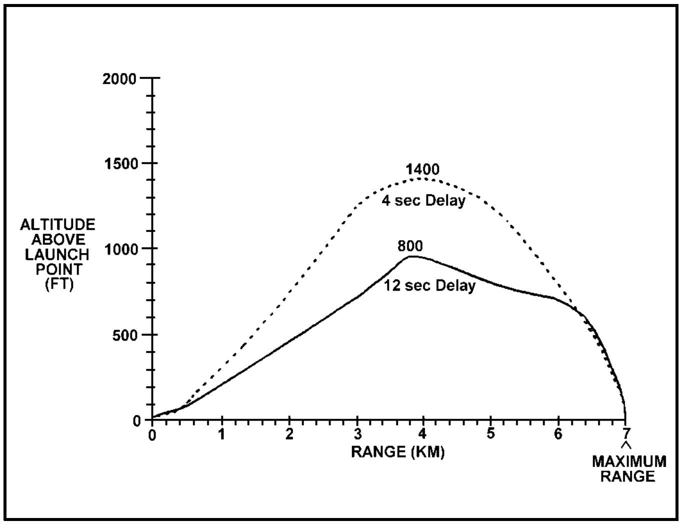

Figure 3. LOAL-DIR Trajectories (AGM-114A)[7]

directs air flow over the missile much like the wings on an airplane, allowing the missile to turn and maneuver toward the reflected laser energy of the target.

The warhead is the last section to contribute to the firing sequence. Upon collision with the target, an impact sensor sends an electrical signal to a fuse in the rear of a copper-lined shape charge, causing detonation. This charge provides the explosive and penetrating force necessary to defeat the armor of a tank or destroy “softer” targets. Only the AGM-114F/K/L models, however, possess the additional ability to defeat modern reactive armor systems.[4] Figure 1 shows a cutaway of the basic Hellfire missile and its sub-components.

## Methods of Employment and Planning Considerations

There are different techniques for tactical employment of the Hellfire missile on the battlefield. These techniques are ultimately driven by the two engagement methods by which the missile can be controlled to the target: autonomous and remote. An autonomous engagement requires the aircraft launching the missile to guide it all the way to the target after the missile is away. In this method, a single aircraft and its crew will locate, identify, fire, and guide the missile until destruction of the target in the same way an M2/M3 Bradley crew employs its TOW missiles. In contrast, a remote engagement requires an aircraft to serve as a launch platform, providing a missile for another aircraft or a ground observer, designating with a laser, to guide the missile to its intended target. A ground designation station such as an FO or Combat Observation Lasing Team (COLT) accomplishes this with lasing devices like the G/VLLD or MULE. With a remote engagement, the air crew is responsible only for delivering the missile toward the general location of the target, but is no longer responsible for its guidance once it leaves the external launch rails. This allows remote engagements to provide one distinct advantage over autonomous engagements. *Using this technique, the launch aircraft is often able to remain masked behind terrain, greatly reducing its visible launch signature while delivering missiles toward the target array, thereby increasing aircraft survivability - a force protection consideration.*

Remote engagements, however, require a great deal more coordination and planning between the “shooter” and the “observer.” This is especially true when aircraft and ground designators, such as the COLTs, are working together. Unimpeded radio communication and information transfer between these elements are a must for successful target destruction and to reduce the risk of fratricide. Ground commanders and operations planners wishing to utilize Hellfire missiles in this manner must be aware of this prerequisite. They must closely coordinate with supporting aviation units for the location of pre-planned aerial battle positions/attack-by-fire positions and ground remote designation positions/observation points to support this air and ground interaction. *On combined arms battlefields with limited terrain for both cover and concealment or observation/fields of fire, this can have serious planning implications concerning land management and clearance of fires.*

In addition to the two methods of engagement, there are four modes of *delivery* that aircrews can utilize when firing the Hellfire missile. These delivery modes are important to consider because they are driven by three important factors: distance to the target, the weather (primarily visibility and cloud ceiling height), and terrain conditions under which the missile will be fired. These conditions will always require careful planning consideration when attempting to integrate air and ground fires into the tactical plan because they affect the relative trajectories of Hellfire missiles when fired. Higher trajectories can have serious ramifications if an attack mission is planned or executed during a period of marginal weather with low cloud ceilings, especially if conducted at maximum standoff ranges. The reason for this revolves around the laser guidance system employed by the missile. *As a general rule of thumb, when a Hellfire missile flies through obscuration (fog, clouds, smoke) or if the designator fails to lase the target properly until impact, the missile loses laser lock and will be lost for good. It will not regain sight of the target, even if designated again.* As previously mentioned, only one model of Hellfire missile, the AGM-114K, has a built-in system to assist in the reacquisition of the target after laser lock-on is lost, but these missiles have yet to be produced and distributed in quantities large enough to ensure that this problem would not be a factor. The AGM-114L when fielded will, however, provide a true fire-and-forget capability.

The first delivery mode is known as the Lock-on Before Launch (LOBL) technique. In this mode, the missile laser seeker acquires and locks-on to the coded laser energy reflected from the target prior to launch. The advantage to using this particular delivery mode is that the air crew is assured that the missile has already positively locked on to the target prior to launch from the aircraft, thereby increasing its $P^h$ and reducing the possibility of a lost or uncontrolled missile. The disadvantages of a

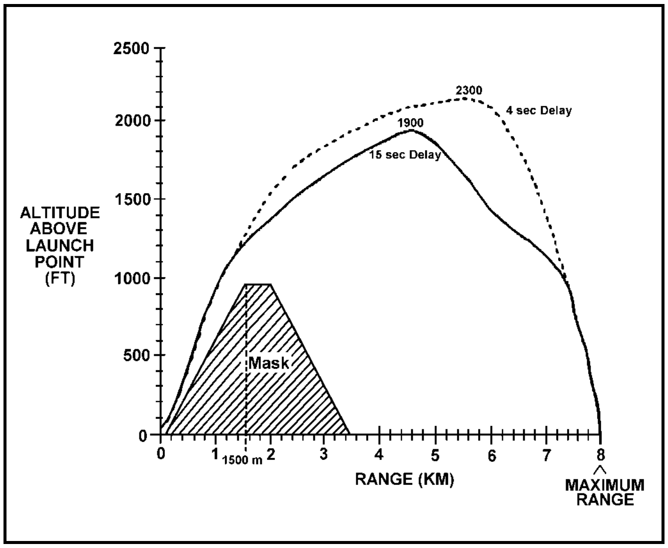

Figure 4. LOAL-HI Trajectories (AGM 114-A)[8]

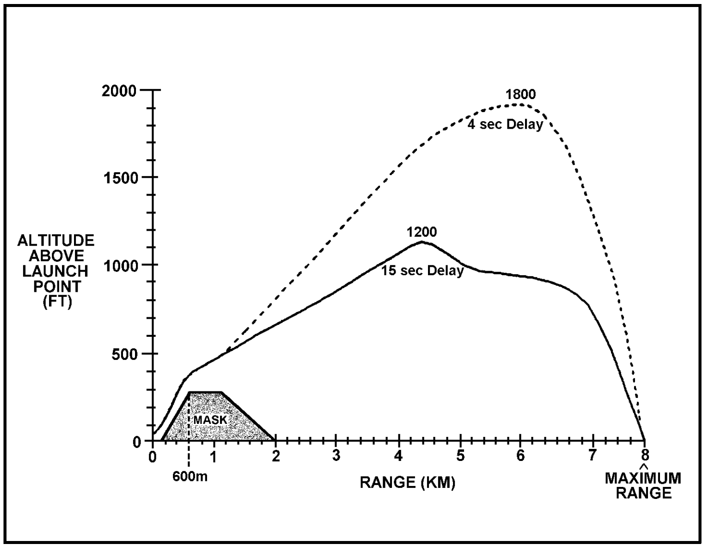

Figure 5. LOAL-LO Trajectories (AGM 114-A)[9]

LOBL delivery revolve around the trajectory of the Hellfire missile as it streaks toward its target. LOBL engagements cause the missile to fly the second highest trajectories of all delivery modes, and the altitude the missile reaches is a function of distance to the target. Simply put, in LOBL mode, the farther the target, the higher the missile flies. Figure 2 shows examples of the maximum trajectories of an AGM-114A missile during different engagement ranges. As the graph in Figure 2 depicts, the missile will reach a maximum altitude above launch point of 1700 meters at its maximum effective range of 7 kilometers. This altitude can be decreased only if the distance between the launch aircraft and the target is reduced. Thus, to compensate for a low cloud ceiling, an aircraft may need to expose itself to threat weapons ranges in order to ensure a successful engagement.

One method to reduce the maximum altitude of the Hellfire's flight trajectory is to select the Lock-on After Launch - Direct (LOAL-DIR) delivery mode. This delivery mode results in the lowest of all trajectories during missile flight because it is employed using a laser designation delay. In this particular mode, the aircraft launches a missile toward the direction of the target before it is designated by a laser. As a result, the missile travels "blind" initially. It will climb slightly, but remain relatively low until the laser is activated after a pre-determined time. Once the missile acquires reflected laser energy, it pitches up to achieve an optimum dive angle at the target. Overall, depending on the length of laser delay time, the maximum altitude reached during the flight trajectory is much lower; a distinct advantage over all other delivery modes. Figure 3 depicts the lower trajectories that may be achieved using LOAL-DIR. A 12-second designation delay would cause the missile to reach its apex at only 800 feet when fired at a maximum engagement range of 7 kilometers. The downside to this method, however, is that air crew is not assured of positive lock-on prior to launch. In addition, if the laser designation delay is too long, the air crew runs the risk that the missile may never actually acquire the reflected energy or that it may lack the maneuver distance and time required to impact on the target. Thus, overall $P^h$ may be reduced.

The last two delivery modes are unique in that they allow the launch aircraft to remain masked behind terrain to reduce its firing signature and increase aircraft survivability. These delivery modes are known as Lock-on After Launch - High (LOAL-HI) and Lock-on After Launch - Low (LOAL-LO). The first mode, LOAL-HI, allows the missile to clear a 1,000 ft. high terrain feature to front of the aircraft, provided the aircraft remains a minimum of 1500 meters away from that terrain feature. In addition, the maximum effective range of the Hellfire is increased to 8 kilometers using this method. This technique is most effective in a remote engagement. The major disadvantage of employing the LOAL-HI method, however, is that the missile flies the highest trajectory of all delivery modes and is most susceptible to a break in missile lock due to penetration of low-lying clouds. Therefore, it requires the fairest of weather conditions to ensure target destruction. As with the LOAL-DIR mode, a laser designation delay can help to lower maximum altitude attained to some degree. Figure 4 depicts typical trajectories achieved at the maximum effective range.

Using the last delivery mode, LOAL-LO, will help to reduce the maximum altitude of the Hellfire trajectory somewhat, but will also limit the size of the terrain mask utilized by the aircraft for survivability. Employing this technique, the missile is able to clear a 260 ft. high terrain feature to the front of the aircraft as long as the aircraft maintains a minimum of 600 meters standoff distance. Maximum effective range of the Hellfire is again extended to 8 kilometers using this technique. Figure 5 depicts the nominal trajectories attained by engagements using this delivery method.

### Limitations of Lasers

As previously mentioned, positive and precise laser guidance of the Hellfire missile until impact is absolutely essential to the probability of hit and target destruction. Like the missile itself, the laser energy used to designate the target is also susceptible to factors of terrain, weather, and distance. Again, these factors must be adequately planned for prior to execution whenever possible to ensure successful target destruction. In particular, five conditions of laser designation or *negative illumination factors* must be taken into consideration and compensated for. These conditions may be present regardless of whether the designation is performed from an aerial platform or a ground-based system. The five negative illumination factors are: beam divergence, attenuation, backscatter, overspill, and underspill.[10]

Beam divergence is a phenomenon that occurs with all directed light energy, but it varies amongst different types of laser designators. Beam divergence is the ever-increasing width of a beam of light from its point of emission to its point of termination. Thus, the general rule of thumb: *the farther the laser designator is from the target, the wider its beam becomes over distance and the wider the resultant spot on the target.* In and of itself, beam divergence does cause a negative illumination of the target, but when combined with certain terrain and weather conditions it gives rise to the other four negative illumination factors, especially over extended ranges.

Attenuation is the overall weakening of the laser beam as it gets wider. This occurs because the concentrated laser energy is diffused as the beam gets wider over distance. In this situation, portions of the beam become “scattered” by airborne particles such as dust and water vapor. These particles absorb or diffract laser energy along the way to the intended target. *Excessive amounts of airborne particles may result in severe attenuation and cause the seeker of the missile not to detect reflected energy from the target*. Conditions that tend to exacerbate attenuation are extended-range engagements planned during periods of rain, fog, and snow. Engagement areas, aerial battle positions, or designation points planned in excessively dusty environments or the presence of battlefield obscurants such as smoke will also contribute to attenuation.

A similar phenomenon occurs due to backscatter. Backscatter is defined as the portion of the laser energy that is “scattered back” or reflected in the direction of the missile by an obscurant. *The result is that backscatter energy competes with reflected target energy and the laser seeker of the missile may lock onto the obscurant instead of the target*. Consequently, a missile may lock-on to a smoke or dust cloud between the target and the designator if it receives a stronger reflection of coded laser energy from this source. Again, careful consideration of the location of laser designators and aerial battle positions in addition to methods of fire distribution and control are needed to reduce the overall effects of backscatter.

Overspill and underspill are products of beam divergence and attenuation, but *are most severe at long designation distances*. Overspill is caused when a portion of the laser spot spills over the top of the target, causing variable portions of the laser beam to pass beyond the target. If a target is engaged from too far away, much of the laser energy may be spilled over onto objects or terrain beyond it, creating intermittent false targets for the missile to hit, instead of the intended mark. With underspill, the opposite is true. At the same extended ranges, the laser spot hits low on the target causing false targets to be illuminated short of the intended mark. As a result, the missile may then hit short without effect.

Beam divergence, attenuation, backscatter, overspill, and underspill are all negative illumination factors that must be understood by everyone, but can only be compensated for by the designators actually executing the mission. Therefore, *mission planners must set the conditions for success by limiting engagement ranges to distances that correspond to maximum effective ranges, and by implementing measures to reduce the negative factors of terrain and weather*. Tactical plans involving air/ground integration and the use of Hellfire missiles must take these factors into consideration to ensure mission success.

### Applications for the Future

So what does any of this information mean to the ground maneuver commander or S3/S3 Air? Commanders and their planners who understand the system will be able to effectively employ it to meet their tactical needs. The scope of this article is not to downplay the effectiveness of the Hellfire missile system. Much to the contrary, the Hellfire remains one of the most effective and lethal weapons on the battlefield today, and will continue to perform in this capacity far into the future. At a unit cost of less than $40,000, it allows friendly forces to destroy an enemy tank worth millions from a distance unparalleled by any other direct fire weapon system.[11] Married to the modern aerial platforms utilized by highly mobile and flexible aviation forces, it provides the ground commander with an excellent means of destroying HVTs/HPTs at times and places of his choosing. Synchronizing its lethal effects with other battlefield weapon systems will allow the commander to mass fires and overwhelm would-be enemy forces, defeating their ability and will to fight. However, not unlike any other weapon system used today, it does have its limitations.

You must plan around these limitations in order to achieve positive tactical results. The Hellfire is quite different from other direct fire weapons; just seeing a target within range *does not* necessarily mean that it can be hit. Additionally, it cannot be stressed enough that thorough and careful planning are essential when selecting aerial battle positions or engagement area locations. When pre-planning JAATs or the use of attached/OPCON attack aviation assets in the ground tactical plan, look closely at forecasted weather minimums for the time period in question. Commanders will want to weigh heavily the odds of successful long-range Hellfire engagements during marginal weather conditions. A combination of low ceilings, low visibility, and extended engagement ranges may result in low probability of hit/probability of kill ratios. The terrain in which the system is to be employed must also be considered. The presence of extensive battlefield obscurants like dust, fog, and smoke could seriously degrade the effectiveness of laser designation systems. Very quickly, a well-planned counterattack against massed enemy armor by a commander’s aviation reserve element could turn disastrous if the conditions do not permit the use of Hellfire missiles, potentially jeopardizing the battle plan. In some cases, decreasing the engagement range will help assist in lowering the flight trajectories of Hellfire missiles, but may, in turn, sufficiently decrease the standoff range and/or limit the terrain available for cover and concealment, thereby exposing the aircraft to threat weapon systems. This decision must be thought through carefully. Task Force Normandy’s preemptive strike on Iraqi radar sites to start the Persian Gulf War might have met with terrible results if the limitations of the Hellfire missile system had not been adequately considered, potentially resulting in a loss of many Coalition aircraft.

Finally, understanding that aviation forces are the primary proponent of the Hellfire missile system, these units are not to be relinquished of the responsibility to coordinate and conduct parallel planning with the ground maneuver forces that they are integrated with. Ultimately, it is the aviation unit that must keep the ground commander informed of what his unit can or cannot achieve. The best means to achieve successful integration of air and ground assets is to incorporate knowledgeable aviation liaison officers early into the ground unit’s planning process to ensure that proper conditions are set to support the ground maneuver tactical plan with Hellfire systems. With a commitment to do this, both air and ground forces will enjoy considerable success on the modern combined arms battlefield. *Target identified, laser on, missile away...*

## Notes

[1] U.S. Department of the Army, *Operations*, Field Manual 100-5, (Washington, D.C.: U.S. Government Printing Office, 1993), pp. 2-2 thru 2-10.

[2] U.S. Army Aviation Center, *OH-58D Hellfire Missile System*, Student Handout 4A/H/L/W-5563-4, (Fort Rucker, Ala.: Aviation Training Brigade, 1995), pp. 56-57

[3] *Jane's Weapon Systems 1986-1987,* (New York, N.Y.: Jane's Publishing Inc., 1987), p. 193.

[4] U.S. Army Aviation Center, *OH-58D Hellfire Missile System*, Student Handout 4A/H/L/W-5563-4, p. 58.

[5] U.S. Army Aviation Center, *Helicopter Gunnery*, Training Circular 1-140, (Washington, D.C.: U.S. Government Printing Office, 1991), p. 6-30.

[6] U.S. Army Aviation Center, *Hellfire Missile System*, Student Handout 15-6443-6, (Fort Rucker, Ala.: Aviation Training Brigade, 1996), p. A-2.

[7] U.S. Army Aviation Center, *Hellfire Missile System*, Student Handout 15-6443-6, p. A-2.

[8] *Ibid.*, p. A-4.

[9] *Ibid.*, p. A-3.

[10] U.S. Army Aviation Center, *OH-58D Hellfire Missile System*, Student Handout 4A/H/L/W-5563-4, pp. 97-98.

[11] Headquarters, U.S. Army Armament, Munitions, and Chemical Command, *Ammunition Book Complete*, (Rock Island, Ill.: HQ, U.S. Army Armament, Munitions, and Chemical Command, 1994), p. 524.

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