PRECISION GUIDED BOMBING WITH THE LANTIRN IN THE F-14B TOMCAT

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Changes from the previous major release will be marked with a bar in the left margin as seen here.

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[1] All images by Heatblur Simulations except for Figure 4 and Figure 9.

One of the biggest and most rewarding challenges in Heatblur's F-14 Tomcat module is crew coordination between the Pilot and Radar Intercept Officer (RIO), and this challenge and reward is most evident when employing Laser Guided Bombs (LGBs) using the Low Altitude Navigation and Targeting Infrared for Night (LATIRN) pod. The LANTIRN is minimally integrated with the F-14's Weapon Control System (WCS), so any LGB employment is "offline" and requires close coordination and teamwork between Pilot and RIO to ensure that the bomb hits its aimpoint. This guide describes the tactical considerations and required switchology for both the Pilot and RIO stations, goes in-depth in how a RIO employs the LANTIRN to find and designate targets, and finally the coordination required to prosecute the designated target.

LANTIRN INTRODUCTION AND SETUP

As indicated in the opening paragraph, the LANTIRN system is minimally integrated with the F-14's WCS, and must therefore be employed using a series of workarounds. First, while the LANTIRN system was designed as a two-pod system for both navigation and targeting, the F-14 only uses the AN/AAQ-14 Forward Looking Infrared (FLIR) targeting pod. The AN/AAQ-14 must be attached to Station 8B (the starboard, or right glove pylon) on the Tomcat, which is the only station wired to handle the pod. For brevity, the AN/AAQ-14 pod will still be referred to as LANTIRN in this document.

The LANTIRN system has its own Global Positioning System (GPS) receiver, and does not communicate with and is not slaved to the Tomcat's Inertial Navigation System (INS) for positional accuracy. This has its own advantages and disadvantages, but the most important takeaway with the LANTIRN's independence is that you can confidently relay both present position and the position of the designated target with confidence to other aircraft (*e.g.* for buddy-lasing) without having to factor the inertial drift of the Tomcat's navigation system. Equally useful, Lat/Long positions provided as target intelligence (either in the brief or real-time cueing by other pilots) can be input as waypoints in the WCS, and slewing between waypoints using the LANTIRN will provide an accurate GPS position to minimize the need to slew the LANTIRN pod after selecting the waypoint. As a result, *RIOs should input target data as waypoints whenever possible so that the LANTIRN can automatically slew between positions on demand.*

This independence also means that the LANTIRN's GPS present position may deviate from the Tomcat's INS present position. Knowing that the situation on the LANTIRN may deviate from your designated waypoints on the RIO's Tactical Information Display (TID) is a point of awareness that helps a RIO cross-check his system.

The other implication of the offline nature of the LANTIRN pod is that the Pilot must drop using the LANTIRN cues on his TV repeater display, and any weapon release is in Manual Mode. This will be covered in a future section.

LANTIRN DISPLAY

This section is not intended to reiterate or replace Heatlbur's manual, but rather to provide a quick explanation of how it applies to the system employment. Figure 1 shows the LANTIRN display on the TID and the TV repeater.

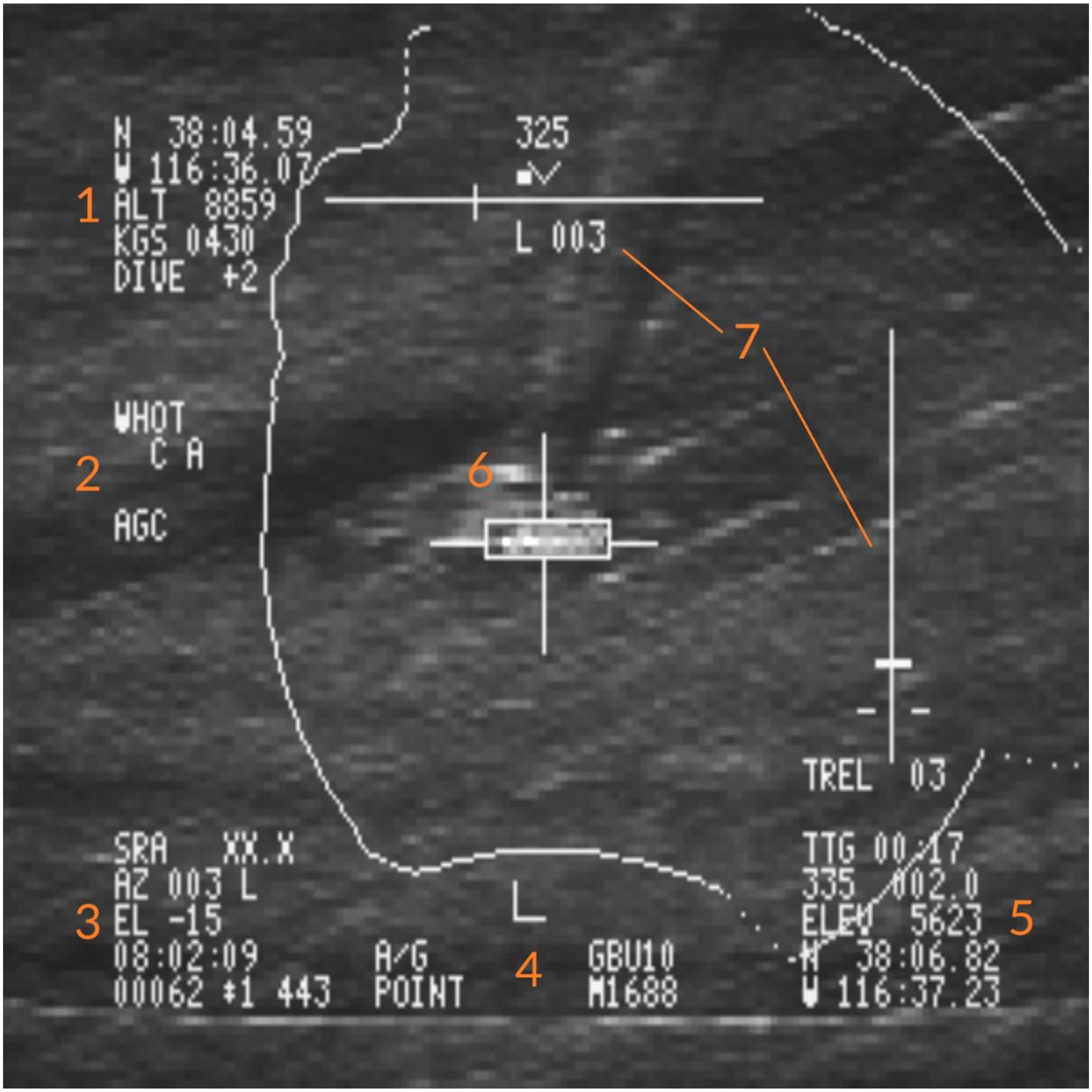

Figure 1 LANTIRN Video Display

Figure 1 #1 shows the aircraft's current position, attitude, altitude, and groundspeed. The RIO can use this to back up the pilot, especially with regards to maintaining altitude.

Figure 1 #2 indicates whether the display polarity is White Hot (WHOT) or Black Hot (BHOT) as well as whether the Gain Control is Automatic (AGC) or Manual (MGC).

Figure 1 #3 shows the slant range, azimuth, and LANTIRN attitude (*i.e.* angle below the horizon). This information is all relative to the target, and can be used to plan and evaluate runs into the target. Slant range is the straight-line distance between the aircraft and the target, and factors both altitude and distance over ground.

Figure 1 #4 shows the LANTIRN Mode (A/A or A/G) and the selected point (either one of the Q-points, Area for ground-stabilized, or Point for point-target tracking. Additionally, Figure 1 #4 shows the selected weapon on the RIO's Weapon Type dial, and should match the LGBs mounted to the aircraft. This provides the ballistic calculation for the drop cue, and must match the actual LGB on the hardpoint in order to drop (*e.g.* you cannot use Mk82L as a substitute for the GBU-12).

Beneath the selected weapon is the laser code used by the LANTIRN. *This does not change the laser code of the weapon, but only what the LANTIRN pod emits.*

Figure 1 #5 shows the target data, including position, elevation, and time for the aircraft to reach the target (Time-to-Go, or TTG). Note that TTG is not the same thing as Time-to-Impact (TTI), which is the estimated time for the released bomb to reach the target.

Figure 1 #6 is the target itself. If it is boxed as shown in Figure 1, then the target is being tracked as a point target.

Figure 1 #7 shows the steering and bomb drop cues once a target has been designated. The pilot must follow the steering cue and release the weapon in time with the drop cue in order to have a successful release.

PILOT

It is the pilot's responsibility to put the aircraft in a position to succeed, both in aerial positioning as well as cockpit configuration. Without regard to the threat environment, the ideal position for the aircraft is from 20,000 feet Above Ground Level (AGL) up to 40,000[2] feet Mean Sea Level (MSL) in a gentle right-hand orbit to keep the pod on the target without having the fuselage mask the LANTIRN. The higher altitude the pilot maintains, the steeper the LANTIRN points and the less likely it is to be masked by the aircraft or other terrain. Additionally, a higher release altitude allows for more time and distance for the LGB to correct in the event the LGB is released under less-than-ideal parameters.

Figure 2 Pilot's Display Control Panel

Figure 3 Pilot's Control Stick

Finally, the pilot must ensure the following switch configuration to allow a weapon drop[3]:

1. Master Mode (Figure 2 #2): A/G
2. Weapon Selector (Figure 3 #3): Off (switch as shown)
3. Master Arm On
4. VDI Mode (Figure 2 #5): TV (recommended)
5. Optional: Wing Sweep set to MAN (bombing mode)[4]

[2] The original LANTIRN pods would not fire their laser above 25k feet, though this limitation does not appear to be modeled in DCS. 40k capable LANTIRN pods became operational in the US Navy in 2001.

[3] Figure 2 and Figure 3 are taken from the Heatblur F-14 online manual, and not all numbers in each figure are germane to this document. Consult the manual for further explanation of the numbers for the Display Control Panel and Control Stick.

If both the Pilot and RIO switch configurations are correct, a fall line with ORD text should display on the Heads-Up Display (HUD) to indicate proper configuration. ORD with a X through it indicates proper configuration, but Master Arm Off (if you wish to hold Master Arm until release is imminent). If the configuration is correct, the Pilot should see indications as shown in Figure 4.

Figure 4 Proper LANTIRN Configuration (Pilot View)

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[4] Wing Sweep to MAN will default the wing sweep to 55 degrees for Bombing Mode. This option is only to provide stability for weapon employment, and may not be necessary for orbiting/buddy-lasing or a level weapon drop.

RIO

The RIO is the primary workhorse with regard to LANTIRN employment, and as such has both armament and display configurations to consider. These considerations will be broken into sections.

ARMAMENT PANEL

For the RIO, the switchology on the Armament Panel (left vertical panel) is critical to allowing the Pilot to drop LGBs. The RIO must ensure the following switch configuration to allow a weapon drop (numbers in parentheses correspond to the switch as shown in Figure 5[5]):

1. WPN Type (1): GBU-10, -12, -16, or -24 as required (this display is repeated on the LANTIRN display as shown in Figure 1 #4)
2. ATTK Mode (2): MAN
3. DLVY Mode (22): STP + SGL (both switches up)
4. Mech Fuse (21): Nose/Tail
5. Elec Fuse (3): INST, DLY1, or DLY2 as required
6. Stations 3-6 (18, 14, 12, 7): Selected (as required)

Figure 5 RIO's Armament Panel

[5] Figure 5 is taken from the Heatblur F-14 online manual, and not all numbers in this figure are germane to this document. Consult the manual for further explanation of the numbers for the Armament Panel.

Once the Pilot and RIO have set up their respective switches, verify that the pilot sees ORD and a fall line in the HUD. If the cues are not present in the HUD, troubleshoot switchology at both stations.

LANTIRN/TID SETUP

Once the LANTIRN pod is attached to Station 8B, the RIO should have an additional controller on the left horizontal panel. This is the LANTIRN controller, and it requires separate controller mapping as discussed in the next section. In addition to the controller, some additional buttons and switches are added behind the stick (Figure 6), and these must be properly configured to employ the LANTIRN.

Figure 6 LANTIRN Control Panel

Immediately behind the LANTIRN stick is the power switch for the LANTIRN system (Figure 6 #1). This must be set to the right-most position (POD) in order to power the system. The system then takes *eight minutes to warm up*, so ensure that you power the system during pre-flight.

Once the system is powered up, The FLIR Standby/Operate button (Figure 6 #2) will illuminate as STBY. Press this button to toggle its function to OPER, during which time it will initialize the LANTIRN pod and then expose its lens to allow targeting. During the initialization process, the OPER light on the button will flash, and the LANTIRN will be ready for use once the OPER light is stable.

The Video toggle (Figure 6 #5) will toggle the TID video display between the Television Camera Set (TCS) and the FLIR (LANTIRN). Once the LANTIRN is in Operate mode, setting this button to FLIR will put the LANTIRN display on the TID.

Finally, the Laser Arm switch (Figure 6 #4) will arm the laser, allowing for slant range determination, aimpoint refinement, and the guidance of LGBs.

LANTIRN CONTROL STICK MAPPING (COUGAR/WARTHOG)

This section will not reiterate the LANTIRN Control Stick section of Heatblur’s manual, but will instead recommend a strategy for mapping your HOTAS stick to the LANTIRN without sacrificing default Hand Control Unit (HCU) functionality at the RIO station. The Cougar/Warthog stick will be used due to its widespread use and its near one-to-one mapping with the LANTIRN control stick. Note that these mapping instructions assume that no TARGET profile is in use, though the author’s TARGET Script includes an F-14 profile with this mapping already in place.

MODIFIER/SWITCH

If you are using a Warthog stick and happen to have a Cougar stick lying around, a second stick would be a great solution and you can bypass this section altogether. However, for people with a single HOTAS, you will want to assign either a modifier or switch in the DCS Options menu to toggle stick functionality between the HCU and LANTIRN Control Stick. The difference between a modifier and a switch in DCS is that a modifier exists for as long as the button or key is held, while a switch acts as a toggle whenever the button or key is pressed. If you use a Warthog Throttle, you can assign one of the switches on the throttle base as a modifier since the button is held for the duration the switch is activated. The author recommends the APU Start switch, which maps to the Warthog Throttle Joy_Btn20.

If you are using a Cougar or similar HOTAS without switches on the throttle base, then you will want to assign a button as a switch (as opposed to a modifier) in the DCS Options menu. Any button on the throttle is fine, so long as you can keep track of what mode you are presently in.

Figure 7 LANTIRN Control Stick

HOTAS STICK MAPPING

Now that your modifier/switch is set, you will need to map the following LANTIRN hats and buttons (Figure 7) to their HOTAS counterparts. The Cougar/Warthog stick will be used as an example. It is critical that if you use a modifier/switch, this button (*e.g.* Joy_Btn20) is added to the mapping so that you don't replace the default HCU functionality. *Note that unless specifically indicated, S3 and S4 in this section refer to the LANTIRN Control Stick, and not the Thrustmaster button nomenclature.*

1. S3 Hat maps to TMS (TM Hat 2)
2. Center Slew Hat maps to Trim Hat (TM Hat 1)
3. S4 Hat maps to DMS (TM Hat 3) with S4 Push mapping to the MMCB (TM Btn S1)
4. FOV Cycle maps to Weapon Release (TM Btn S2)
5. The two-way hat (LANTIRN Master Mode) maps to CMS (TM Hat 4) Left
6. The two-way slider maps to CMS Forward/Aft
7. The two-stage trigger maps to both stages of the HOTAS trigger (TM TG1 and TG2)
8. Latched laser fire button maps to the paddle switch (TM Btn S4)
9. White Hot/Black Hot (normally Center Hat Slew Push) maps to CMS Right (Cougar/Warthog) and CMS Push (Warthog)

RIO LANTIRN EMPLOYMENT

Once the LANTIRN is powered up and placed in to Operate, the RIO must place the TID Mode (Figure 8 #10) to TV (the bottom-most selection) to see the LANTIRN in the TID. Make sure FLIR is selected on the Video Toggle button (Figure 6 #5), and the RIO should see FLIR video on the TID. The next thing the RIO should do is set the LANTIRN mode to A/G to allow slewing to waypoints and ground stabilization. To reiterate the first section, RIOs should take advantage of this capability by adding as many target waypoints as possible into the WCS so that the LANTIRN can quickly be slewed to targets.

Figure 8 TID Display Options

For target acquisition not slaved to a waypoint, QHUD[6] (S4 Up) and QSNO (S4 Down) modes can slave the LANTIRN to the HUD waterline or 15nm on the ground in front of the aircraft (*i.e.* snowplow) respectively.

Once the LANTIRN is in A/G mode, cycle S3 Left/Right to cycle between waypoints until you find your target area. Then to manually slew to a target, first select S4 Down to ground stabilize the seeker (AREA will display at the bottom of the screen). From here the RIO can manually slew to the target, then do a full trigger press to designate the target. Don't be afraid to designate early once in the target area. One can always re-designate the target, and designating the target allows the RIO to go right back to where you were (S4 Right) if the LANTIRN is masked or loses ground stabilization. In fact, designate early and often, then use S4 Right as a "panic" button upon losing the target.

PILOT/RIO COORDINATION (SELF-LASING)

Up to this point, the efforts have been mostly independent (albeit coordinated), with both the Pilot and RIO configuring their respective consoles for weapon employment and the Pilot maintaining an unmasked position while the RIO searches for targets. This changes once the target has been designated and the Pilot and RIO act to prosecute the target.

PRE-RELEASE (RUN-IN)

Once the RIO has designated a target, steering and bomb release cues will appear on the top and right sides of the LANTIRN display. This is where it is most important for the RIO to coordinate with the pilot, who must fly these cues and manually drop the LGB. Assuming a 20k foot altitude, the author recommends extending to 10nm slant range from the target on initial practice runs to practice line-ups and release cues. After some practice, aircrews can be more aggressive and start turns into the target at 8 and then 6nm. The higher altitude the aircraft is, the farther away it needs to start its runs, as the parabolic flight path of the LGB will require a drop at a more distant slant range.

While the pilot is making major corrections to turn into the target, he won't have a VDI and he will likely have his head outside in order to maintain altitude and attitude. As such, the RIO needs to call corrections to target (*e.g.* 90 right, 60 right, 30 right, 15 right), with the pilot easing his turn as he gets closer to the run-in-heading. Once the pilot is within about five degrees of the desired run-in-heading, he can go head down to the LANTIRN repeater and make minor corrections to line up the target. However, the RIO should still make line-up calls along with time to release calls so that the pilot can still be primarily heads-up to fly and look for threats. The pilot can add the LANTIRN to part of his scan, but should rely on the RIO to provide primary steering and drop cues. The pilot should follow these cues all the way to bomb drop, and must manually release the bomb when the tick on the vertical line passes the release cue.

Bottom line: the pilot must concentrate on flying, which includes maintaining altitude and a consistent bank angle to keep the LANTIRN unmasked. The RIO must provide verbal steering guidance and situational awareness in the form of LANTIRN cues so that the pilot can keep his head outside the cockpit.

POST-RELEASE (MAINTAIN LASER)

Once the bomb is released, the LANTIRN display changes from Time-to-Release to TTI. This phase of prosecution is just as important as the process leading up to release, as now the RIO needs to lase the target while the pilot needs to make sure the LANTIRN remains unmasked during the bomb's duration of flight. Understanding the geometry of the situation is crucial to ensure that the LGB can receive its guidance to the target in its terminal phase.

Since LGBs use full deflection of control surfaces to correct to target (known as "bang-bang," as opposed to partial or analog deflection), turning on a laser too early can cause a bomb to overcorrect and lose the kinetic energy it requires to reach the target. Therefore, a rule of thumb is to only lase the target once the TTI is 10-15 seconds away (with possibly

[6] QHUD is the boresight mode associated with the LANTIRN A/G master mode. The A/A master mode uses QADL, which slaves the LANTIRN to the Armament Datum Line (ADL), or gun cross. A/A mode exceeds the scope of this document.

more time if a bomb is released under unfavorable parameters). This means that it is not so important to prevent masking during the LGB's flight time, but rather to *ensure that the pod is unmasked during the bomb's terminal phase of flight*. Again, this is where a high-altitude release allows for more flexibility in terms of steeper slant range geometry as well as allowing additional flight time for advantageous positioning. Under a minimal threat environment, this may not be a factor, as the pilot can fly toward the target after release and then maintain a shallow right-hand orbit to keep the LANTIRN seeker away from the masking limits. However, if orbiting or overflying the target is not a tactically sound option, it could behoove the pilot to make an aggressive left turn (temporarily masking the LANTIRN) so that he can maintain visibility to the target off the starboard side of the aircraft during the bomb's terminal phase. This should be coordinated between the Pilot and RIO ahead of time. The RIO should immediately call the TTI after the pilot calls the weapon release (as well as the intended laser time if it is greater than 15 seconds). This lets the pilot know how long he has to make the maneuver and get back into position to lase the target. Tactical geometry is beyond the scope of this guide, but this example illustrates the required level of coordination between Pilot and RIO to ensure the bomb reaches its aimpoint.

Bottom line: the Pilot must maintain an attitude and altitude to keep the laser unmasked during the time required for the bomb to guide to its target. The Piot and RIO must maintain communication so that the pilot knows when this required time of guidance begins, and when he is once again free to maneuver.

POST-IMPACT (NEXT TARGET)

As soon as the bomb hits, if there are other targets in the immediate vicinity the RIO should quickly press S3 Down to ground stabilize, then immediately slew to and designate another target. The targeting doesn't need to be precise, but designating in the target area is critical to develop cueing prior to the pilot making an aggressive maneuver to extend (thereby masking the target area). The RIO should designate, tell the pilot, and then the pilot knows he can now maneuver without restriction. There should now be cueing to extend and determine another run-in-heading, and at the very least the RIO can press S4 Right to slave the LANTIRN to the designated target, at which point he can refine his targeting solution. If the bomb missed the target, the RIO should call the miss and immediately redesignate the target (full trigger on the same position) for the next run.

Note: it is possible to redesignate a target prior to bomb impact (going full trigger while holding half-trigger for the laser makes this easy to do). If this happens, TTI cues will be replaced with a new release cue. You can still lase the target, but you need to perform a mental countdown based on the original TTI.

AIRCREW COORDINATION (BUDDY-LASING)

LANTIRN tactical employment is challenging enough with a single aircrew, but adding aircrews for Precision Guided Munitions (PGM) employment based on the LANTIRN's laser (*i.e.* "buddy-lasing") adds another dimension to the complexity of target prosecution. There are reasons for buddy-lasing, such as allowing a single entity (the F-14) to control all weapons employment, allowing other aircraft to employ weapons without breaking stand-off ranges, allowing other aircraft to place a weapon on a hardpoint instead of a targeting pod, or even providing precision targeting capability for aircraft that cannot self-lase (*e.g.* F-5E or Mirage 2000C). In this tactical situation, the RIO is the natural choice to coordinate the operations of all aircraft in the target area, and should maintain control of the tactical picture. *All coordination elements between the Pilot and RIO discussed in the previous section must be in place before taking on this new tactical dimension.*

The most important requirement for coordination is aircraft deconfliction. Simply put, the designating aircraft (F-14) and the aircraft delivering ordinance (*e.g.* F/A-18 with GBU-12) *must never simultaneously occupy the same patch of airspace*. Deconfliction can be accomplished with altitude bands, flight boxes, or combinations of both. Such considerations are based on the tactical scenario and are beyond the scope of this document, other than 1) recommending that the F-14 remains at a higher altitude than the other aircraft to ensure that weapons do not fly through the F-14's airspace and 2) indicating that deconfliction is of vital importance to all aircrew and a primary concern for the RIO.

The following factors must also be coordinated between aircrews.

LASER CODE

Matching the LANTIRN's laser code to the desired munition is fundamental, yet easy to overlook. Aircraft that do not have a digital bus (F-5E, Mirage 2000C, F-14) must have their munitions' laser codes set on the ground, and cannot change these laser codes in flight. Consequently, it is the RIO's responsibility to get the applicable laser codes from the other aircraft and input the appropriate code into the LANTIRN using slider switch down and the S4 hat.

For aircraft with a digital bus (*e.g.* F/A-18), the laser code can be changed by the other aircraft to match the F-14 or reduce workload for the RIO (*e.g.* by utilizing a laser code already in use by a F-5E). Still, the laser code on the delivery platform must match the laser code for the LANTIRN, and the RIO must coordinate this with the other aircraft.

TARGET/AIMPOINT COORDINATION

While the F-14 is responsible for target designation to ensure the PGM receives terminal guidance, the aircraft firing the PGM (hereafter "Shooter") must be in proper parameters to release the weapon. In short, this requires the aircraft to know where to go and what to shoot.

The RIO as both the coordinator and the one with the target knowledge must convey this information to the Shooter. Depending on the aircraft, this could be as simple as providing a latitude, longitude, and elevation of the aimpoint and having the Shooter input these coordinates as a target waypoint. Since these coordinates are GPS-based, inertial drift does not compound the accuracy issue; therefore the only accuracy concerns apply to the Shooter (*e.g.* Mirage 2000C INS). In the event the Shooter cannot enter a waypoint, a visual "talk-on" may be required to provide the Shooter with the visual cues to enter weapon release parameters.

TIME ON TARGET AND COORDINATED DESIGNATION

Once the RIO and the Shooter share understanding with regard to the desired aimpoint, the most complicated phase of this evolution is the coordinated release and terminal guidance. What this means is that the Shooter must release the weapon at a time where the F-14 is capable of providing unmasked designation either in the terminal guidance phase (LGB) or throughout the weapon's time of flight (AGM-65E laser guided Maverick). This further complicates the tactical geometry discussed in the self-lasing section.

PRE-RELEASE

Ideally, the Shooter should be entering weapon release parameters at the same time the F-14 begins its time in the window during which the laser can remain on the target unmasked. This can be especially tricky with the AGM-65E, which when launched as stand-off range requires significant flight time to the target and laser designation both prior to launch and during the entire time of flight. It is incumbent on the F-14 Pilot to fly a path that maximizes the laser's exposure to the target, as well as on the Shooter to quickly get into firing parameters. The RIO coordinates both efforts to ensure that the Shooter enters weapons release parameters at the same time the F-14 enters its lasing window.

Much of this is learned with experience (on the part of the RIO and the pilots of both aircraft), as no situations are identical. However, one thing that all parties should agree upon is the approximate time to begin the prosecution. For example, if the Shooter says he will be in firing parameters in fifteen seconds, the F-14 Pilot must determine if fifteen seconds is enough time to get into position to maximize his lasing window. If making the window in this timeframe is infeasible, the Shooter must be notified and a new run-in time must be negotiated. This is likely to be a fluid and iterative process, requiring flexibility, patience, and constant communication between the F-14 and the Shooter.

Once a run-in time has been established, *it is incumbent upon the Shooter to enter release parameters on time*. A Shooter that is slow to turn in on the target or calls for the turn while well outside of the release parameters may squander a critical portion of the F-14's lasing window. Conversely, a Shooter that enters weapon parameters too early may end up releasing early or breaking stand-off range while waiting for the AGM-65E to acquire the target. Either way, unsynchronized weapon employment and designation could result at best in the waste of a weapon and at worst the loss of aircraft for due to unnecessary threat exposure. The timing problem is exacerbated with the AGM-65E, since the laser must be on for the target acquisition as well as the missile's entire duration of flight.

POST-RELEASE

Once the weapon is released, the Shooter must make a weapon release call on the radio so that the F-14 knows that a PGM requiring terminal guidance is inbound. Regardless of the weapon employed, the RIO should immediately start the stopwatch in the cockpit by pressing the button shown in Figure 9.

Figure 9 RIO Stopwatch

At this point, further coordination between the Shooter and F-14 may be required. Since the F-14 did not release the weapon, the LANTIRN has no TTI countdown. This must be mentally calculated by the RIO, who will need to know when to begin lasing (in the case of LGBs) or when to realize that the weapon missed its target and cease laser fire.

If the Shooter has TTI information, he should pass this information to the RIO along with his weapon release call. Based on the Shooter's capability and assuming coordination with the RIO, the Shooter may wish to make periodic TTI updates to the RIO. In the absence of TTI data, distance to target (ideally slant range, otherwise ground distance and altitude), and airspeed should be provided to the RIO. The RIO can then compute approximate time of flight based on the equation

$$TTI = 3600 * X / V_{0x}$$

where X is slant range to target in nautical miles and V_{0x} is the Shooter's airspeed in knots[7]. The 3600 is to convert TTI from hours to seconds. It is entirely possible that the Shooter is providing the RIO the slant range already when he calls the distance at the time of release. This should be clarified in advance.

For an AGM-65E release, estimated distance to target should be communicated to the RIO, who can estimate flight time based on the missile traveling 10nm/min[8].

[7] http://www.f-16.net/forum/viewtopic.php?t=1841. For this calculation, groundspeed is preferable to true airspeed, and true airspeed is preferable to indicated airspeed.

[8] The AGM-65 travels 1150kph (per Air Force Technology) which translates to 621kts. For simplicity of calculation and to allow for a conservative time-of-flight, 600kts is used, which translates to 10nm/min.

AVIATOR MATH

The speed at which events occur means that the RIO must quickly do the math in his head. Ultimately, speed of these calculations matters much more than precision, and this all amounts to an estimate of when to lase a target and how long to maintain that laser on target. Therefore, "Aviator Math" should be applied to arrive at a time estimate quickly enough to be tactically useful.

SLANT RANGE

As mentioned previously, slant range is the straight-line distance between the aircraft and the target, which includes both altitude and distance over ground. If the altitude and distance over ground are two sides of a right triangle, the slant range is the hypotenuse. Since X is the slant range, knowing the vertical (*y*, altitude) and horizontal (*x*, distance) components of the right triangle will allow the RIO to determine the hypotenuse. However, the tactical problem does not have time for trigonometry calculations, so estimates must be used. The important factor of the estimate is that it rounds up so that the error is skewed to a longer laser time.

Given the parabolic drop of the bomb, the right triangle is likely close to isosceles, meaning that the *x* and *y* components of the triangle are probably close to being equal. The RIO can confirm this by taking the altitude of the Shooter at the time of weapon release (in thousands of feet), then dividing by 6 to determine the *y* component in nautical miles. This can be quickly compared with the *x* component to determine whether the triangle is isosceles. With an isosceles triangle, the hypotenuse is the horizontal or vertical component multiplied by the square root of two, or 1.414. Therefore, if the bombing triangle is reasonably isosceles the RIO can multiply the distance by 1.5 to determine slant range. If the triangle is not isosceles (*e.g.* slow aircraft dropping from high altitude), then linear interpolation can be used with a smaller number (*e.g.* 1.25) against the larger component (*e.g.* the altitude when referring to the slow aircraft). At this point, even the altitude itself could be used in lieu of the hypotenuse, as the timeliness of the calculation is more useful than the accuracy of the calculation.

EXAMPLE #1

The Shooter, a Mirage 2000C, drops a GBU-12 from 20,000 feet at 450kts ground speed, and the distance to target on his INS is 3nm. We know his INS is calculating his position over the ground and thus is not factoring slant range. Therefore, we divide his altitude in thousands of feet (20) by 6, which is 3.33 or very close to 3. One could also just figure that 20k is close to 18k, which is 3nm. Therefore, the bombing triangle is isosceles with two sides equal to 3nm. Multiplying 3 by 1.5 gives a slant range of 4.5nm. TTI = 3600*X / V_{0x}, or 3600*4.5/450. You can do quick algebra to come up with the following answer:

TTI = 3600 sec/hr * 4.5nm / 450 nm/hr			=>	3600 **sec**/~~hr~~ * 450 ~~nm~~ / 450 ~~nm~~/~~hr~~
3600*4.5/450	=>	3600*4~~.~~5/4500	=>	3600*45/4500
3600*45/4500	=>	36~~00~~*45/45~~00~~	=>	36*45/45
36*45/45	=>	36*~~45/45~~	=>	36*1
36 seconds				

EXAMPLE #2

The same Mirage 2000C drops from 25000 feet at 400kts true airspeed, and the distance to the target on the INS is still 3nm. The altitude (25/6) equates to just over 4nm, so this is not quite an isosceles triangle. Linear interpolation for the hypotenuse multiplier would be between 1.414 and 1.0, which would equate to approximately 1.3 in this case. Since we're doing simple math, we can go with 1.25, which multiplied by 4 gives us 5nm for X.

TTI = 3600*5/400				
3600*5/400	=>	36~~00~~*5/4~~00~~	=>	36*5/4
36*5/4	=>	[36/4]*5	=>	9*5

45 seconds

EXAMPLE #3

Take the same Mirage 2000C parameters in Example #2, but reduce his speed to 350 kts. To simplify the math, we want the airspeed to be a multiple of 60[9]. In this example, we will change the airspeed to 360kts[10].

TTI = 3600*5/360
3600*5/360 => 350~~0~~*5/36~~0~~ => 360*5/36
360*5/36 => [36*10]*5/36 => 36/36*10*5
36/36*10*5 => ~~36/36~~*10*5 => 1*10*5
50 seconds[11]

Important: the conservative nature of these calculations in general (i.e. rounding up simplified numbers) means that these numbers should not be used to determine when to <u>*begin*</u> *lasing. It may be prudent to lase the target for at least an estimated 20 seconds based on these calculations to ensure that the laser guidance is in place for at least 10-15 seconds.*

EXAMPLE #4 (AGM-65E)

A F/A-18C Hornet launches an AGM-65E laser guided Maverick at a target the F-14 is lasing. The Hornet fire control system provides a slant range of 10nm. As previously mentioned, the Maverick travels at 600kts, or 10nm/min. For simplicity and conservative calculation, the speed of the Hornet at launch is not factored into the equation.

TTI = 10nm / 10nm/min => 10~~nm~~ / 10~~nm~~/min
10/10 => 1/1
1 min

Converting to seconds:

1 min * 60 sec/min => 1 ~~min~~ * 60 sec/~~min~~
60 seconds

EXAMPLE #5 (AGM-65E)

The Hornet in Example #4 (AGM-65E) launches the same Maverick, but this time at 8nm slant range.

TTI = 8nm / 10nm/min => 8~~nm~~ / 10~~nm~~/min
8/10 => 0.8/1 => 0.8 min
0.8 min * 60 sec/min => 0.8 ~~min~~ * 60 sec/~~min~~
0.8 * 60 => ~~0.~~8 * 6~~0~~ => 8 * 6
48 seconds

[9] Airspeeds with multiples of 60 (*e.g.* 300, 360, 420, 480) are normally used both during flight planning and in-flight to simplify calculations, as airspeed in knots divided by 60 will indicate the number of nautical miles traveled per minute.

[10] Alternatively, changing the time multiplier in Example #3 from 3600 to 3500 would simplify the math and result in the same answer.

[11] Since the airspeed in Example #3 was increased, the calculated TTI may be slightly short. In this case, adding five seconds to the estimated TTI is prudent to ensure a conservative time window to allow for lasing.

If all goes well the Pilot and RIO should see a satisfying image on their TV display similar to Figure 10! At this point, if the stopwatch was used, it should be stopped and reset to prevent possible issues with additional buddy lasing.

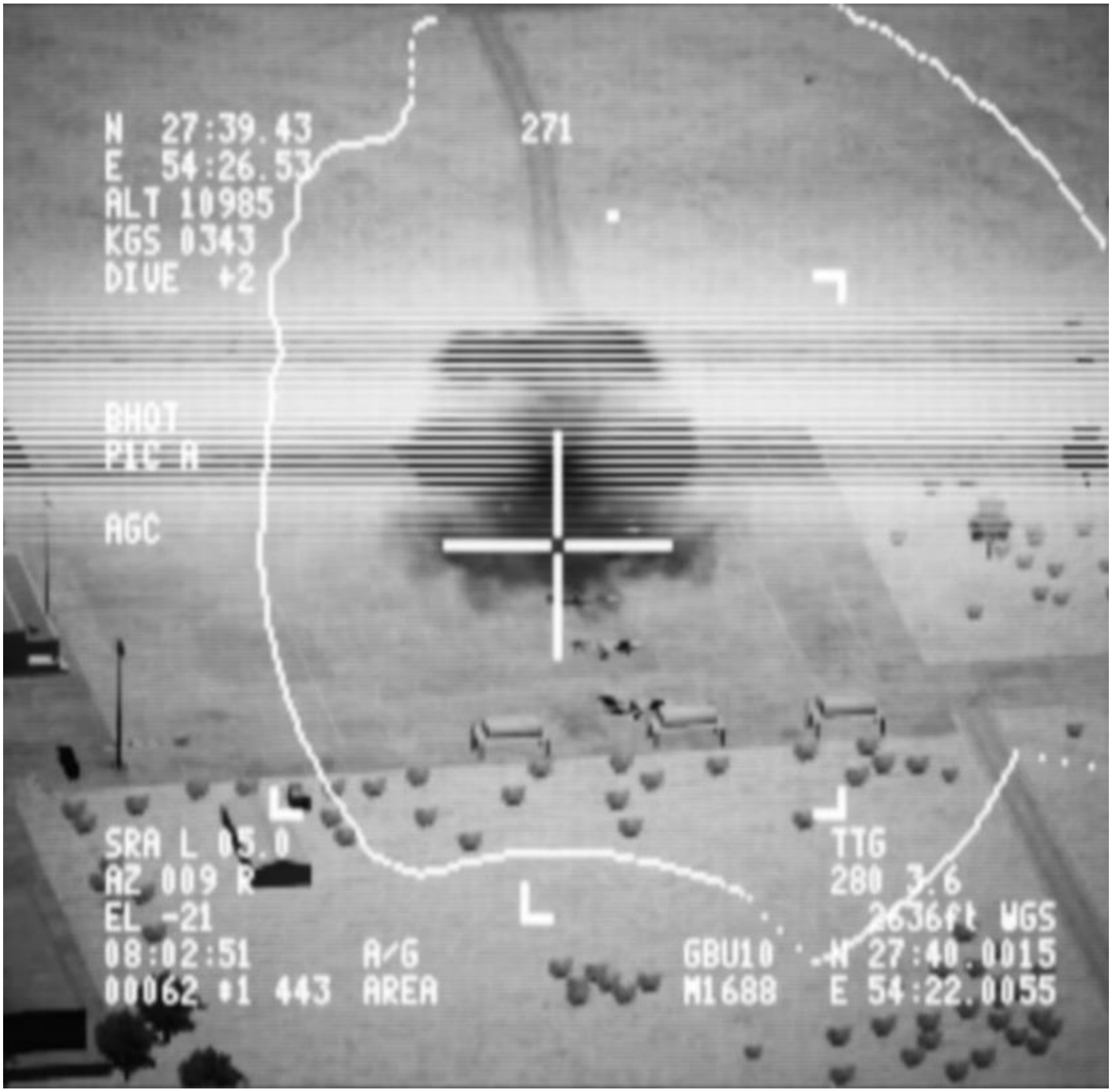

Figure 10 A Job Well Done!

APPENDIX A: PILOT AND RIO CHECKLISTS

This appendix includes Pilot and RIO checklists which can be printed out for quick reference.

PILOT CHECKLIST

INITIAL CONFIGURATION

1. Master Mode..A/G
2. Weapon Selector (Stick)......................................Off
3. Master Arm..As Required (On)
4. VDI Mode...As Required (TV)

RUN-IN

1. Altitude ....As Required
2. Wing Sweep ....As Required
3. Master Arm...On
4. HUD ....Verify ORD/Fall Line
5. Steering...Correct (per RIO)
6. VDI Mode..TV
7. At TTR = 0, Weapon Release Button...................Press
8. Weapon Release ....Notify RIO

POST-RELEASE

1. Maneuver for Laser Designation ....As Required (Right Orbit)
2. Upon Laser Off...Coordinate with RIO
3. New Run-In ....Extend as Required

RIO CHECKLIST

PRE-TAXI

1. LANTIRN Power Switch .... POD

INGRESS

1. FLIR Standby/Operate button .... OPER
2. Target Waypoint(s)... Entered as Required

INITIAL CONFIGURATION

1. WPN Type .... As Required (GBU-*xx*)
2. ATTK Mode .... MAN
3. DLVY Mode.. STP+SGL
4. Mech Fuse .... Nose/Tail
5. Elec Fuse .... As Required
6. Stations 3-6.. Selected as Required
7. TID Mode .... TV
8. Video Toggle Button .... FLIR
9. Laser Arm .... ARM
10. Laser Code .... As Required

RUN-IN

1. Steering and Time to Release .... Notify Pilot
2. Aircraft Altitude .... Verify

POST-RELEASE

1. At TTI of 10-15 Seconds, Laser .... On
2. Laser Designator.. Maintain as Required
3. Upon Hit .... Notify Pilot
   Upon Miss .... Redesignate Target

RIO CHECKLIST

BUDDY LASING

1. Weapon Release Time .... Coordinate
2. At Weapon Release Time, Laser .... On as Required
3. On Weapon Release, Stopwatch .... Start
4. TTI .... Calculate
5. Post-Release Checklist... Execute
6. Stopwatch .... Stop and Reset

TTI CALCULATION

$TTI = 3600 * X / V_{0x}$

where TTI is in seconds (the 3600 multiplier), X is the slant range in nautical miles, and V_{0x} is the Shooter's airspeed in knots (preferably groundspeed or true airspeed).

SLANT RANGE CALCULATION

- Divide Shooter's altitude in thousands of feet by 6 to determine altitude in nautical miles.
- If distance over ground to target is approximately equal to the Shooter's altitude, multiply the distance by 1.5 to determine slant range.
- Otherwise, determine slant range by multiplying the greater value (distance or altitude) by a linearly interpolated value between 1.0 and 1.4.

AGM-65E TTI CALCULATION

- V_{0x} = 600ktas, which translates to approximately 10nm/min.