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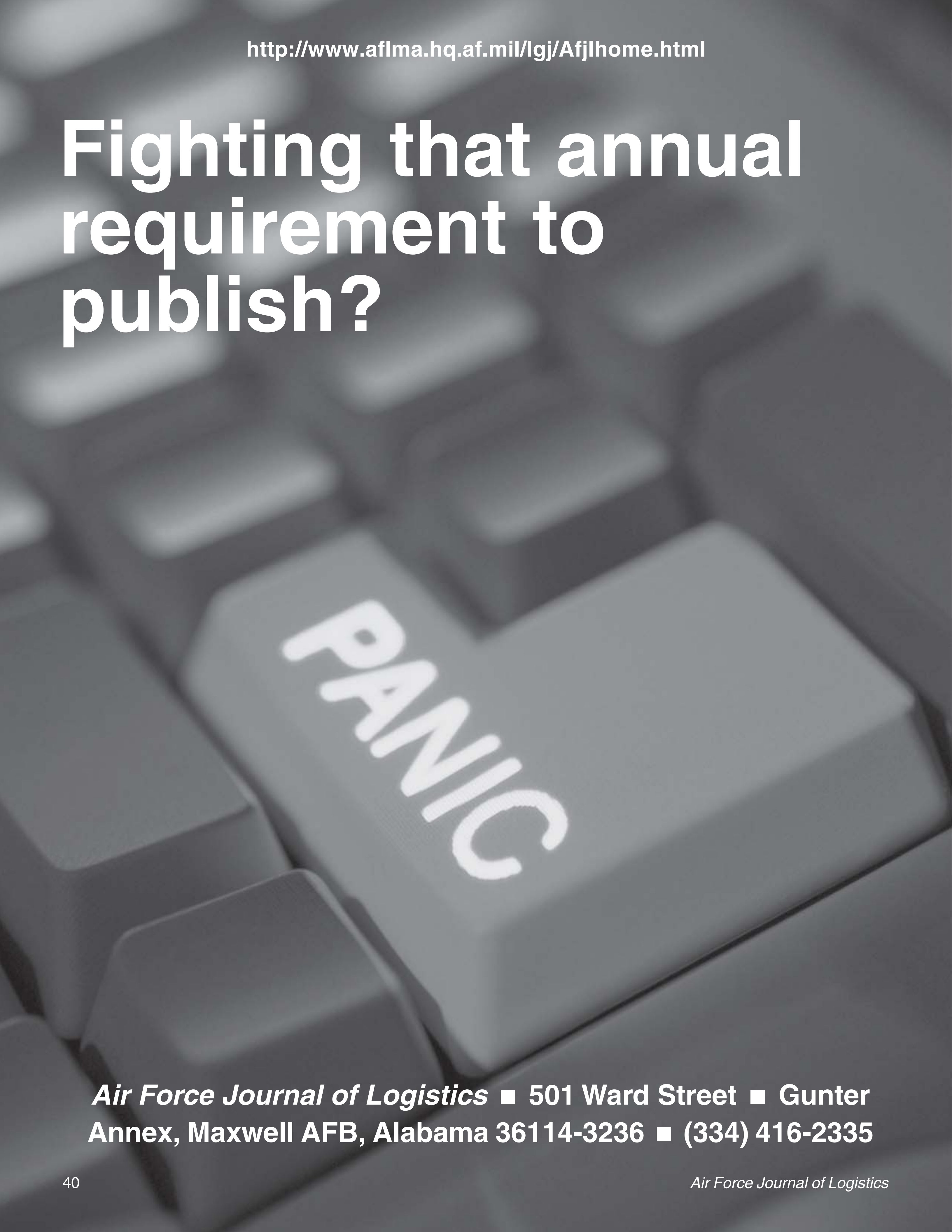
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One of the tools available to Air Force officers to assist them in safely integrating a new program is Operational Risk Management (ORM). ORM is a six-step process based upon four primary principles—accept no unnecessary risk, make risk decisions at the appropriate level, accept risk when benefits outweigh the costs, and integrate ORM into the planning stages of an operation.

contemporary issues

Risk Analysis: F-16 Block 60 FLIR-Assisted Landing Instruction

"Risk Analysis: F-16 Block 60 FLIR-Assisted Landing Instruction" reviews the evolution of the F-16 Forward Looking Infrared (FLIR) system, specifically how the FLIR applies to the newest F-16, Block 60 under contract by the United Arab Emirates (UAE). Part 1 of this article examines the history of FLIR systems prior to the F-16 Block 60 series. Part 2 investigates the hazards associated with landing an F-16 at night, in addition to the potential utility of a FLIR-assisted landing. Finally, in Part 3, the authors present an Operational Risk Management analysis of the integration of teaching FLIR-assisted landings to new UAE Block 60 pilots. Based on this structured risk analysis, the authors recommend introducing IFTS FLIR-assisted night landings during the student's second night sortie. This recommendation follows the logic that the student is already somewhat familiar with the IFTS from using it as a head's-down sensor during the day. On the second night sortie, they suggest having the student use the FLIR to identify the runway environment and then to turn the FLIR down before actually touching down. This reduces the risks of having a night landing mishap. Additionally, they suggest having the student's first night sortie dedicated to standard night instruments and non-FLIR-assisted landings. This allows the emphasis to be on a night instrument cross-check and normal night visual landing cues, thereby giving the student a solid foundation to build his night habit patterns. If the intention becomes to teach an additional IFTS capability, extra night sorties can be added toward the end of the training program. This recommendation safely incorporates the IFTS in the initial sorties, gives a solid night instrument background to the student, and gives the flexibility to build upon the student's IFTS procedures with additional IFTS night sorties later on in the program as dictated by the tactical requirement.

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F-16 Risk Analysis: Block 60 FLIR-Assisted Landing Instruction

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Introduction

Some of the greatest advances in infrared (IR) technology have occurred in military aviation. Through the use of IR imaging equipment, military aviators are now able to mitigate some of the risks of flying in low light and night conditions. This technology is based on the measurement of the thermal energy of an object against its background. By distinguishing small variations in thermal radiation, IR equipment can display a thermal image on a monitor.[1] This enables one to see in total darkness, through fog, and in other low visibility settings. In military aviation, this IR scene is usually displayed to the pilot on a small screen that must be referenced while flying. The result is similar to looking at a small black and white television screen commonly associated with surveillance cameras. The biggest difference is that the pilot is not seeing a representation of visible light on the display, but rather a representation of IR light and what the IR world looks like. The implications of bringing this thermal sensing capability into the cockpit are immense. Whereas before, when military aviators operated at night with decreased effectiveness due to little or no awareness of the outside horizon and surrounding terrain, IR sensors can now provide distinct scene detail of the current flying environment.

In the F-16, these IR sensors are incorporated into what is called the Forward Looking Infrared (FLIR) system. The F-16 FLIR is a *forward* sensor because it is fixed mainly to view what is directly in front of the aircraft. It is also a forward sensor in that it is displayed to the pilot through the aircraft's heads-up display (HUD). For example, the pilot is able to view an IR picture of the world by looking straight ahead without having to reference a small screen imbedded somewhere heads down in the cockpit.

This article reviews the evolution of the F-16 FLIR, specifically how the FLIR applies to the newest F-16, Block 60 under contract by the United Arab Emirates (UAE). Part 1 of this article examines significant historical FLIRs prior to the F-16 Block 60 series. Significant predecessor aircraft, as well as conflicts in the recent past, are examined to show their impact on current FLIR philosophy. Part 2 of this article investigates the hazards associated with landing an F-16 at night, in addition to the potential utility of a FLIR-assisted landing. Finally, in Part 3, a United States Air Force Operational Risk Management analysis of the integration of teaching FLIR-assisted landings to new UAE Block 60 pilots is provided

Background

Predecessor FLIR technology was originally developed by the United States Navy to help identify and target enemy forces.[2] These early systems were expensive, large, and heavy. The incorporation of modern FLIR in military aircraft was influenced both by technological progress (for example, reduction in size, weight, and cost; improvement in capabilities) and by combat necessity. In 1965, the existing combat necessity of the United States military was winning the war in Vietnam. At this point in the conflict, the enemy at the time, the Viet Cong (VC), dominated the night.[3]


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South Vietnamese Army outposts were routinely attacked by night assaults of the Viet Cong. Even though the United States maintained a very capable air arsenal that included 149 helicopters, the VC would almost always hear the noisy aircraft. They would quickly withdraw as the helicopters approached. In an effort to affect the night war in Vietnam, a quiet observation aircraft was recommended to orbit at dangerously low attitudes above the VC at night, while observing the enemy through the use of the then current Night Optical Device technology.[4] The result of this commission was the development of the Y0-3A Quiet Star aircraft. In January 1968, the Quiet Star arrived in theater, and soon began flying combat missions with great success. The observers in the front of the aircraft were able to identify many targets, particularly VC resupply boats moving down the Mekong River from Cambodia.[5] These observers initially carried hand-held Starlight scopes to aid them in target acquisition.[6] The Starlight scope evolved from technology first developed during World War II, and was based upon image intensification.

Image intensification gathers ambient light from the moon and stars and then intensifies this light. These systems operate by amplifying light in the Near IR/visible spectrum, and have led to the modern invention of night vision goggles or NVG.[7] As the use of image intensifying technology began for military aircraft in the Vietnam War, so did the use of Mid IR sensors in military aircraft. History shows that the Vietnam War is the beginning of the split between NVG and FLIR, both of which greatly enhance night military aviation operations. The primary difference between the two technologies lies in the operating wavelengths required. As mentioned earlier, NVGs require a minimal amount of ambient visible light to be present, and that there is nothing obscuring visibility (for example, fog, smoke, dust or haze).[8] FLIRs, on the other hand, operate solely in the middle IR range, and require no ambient light to be present. FLIRs can see in total darkness or obscured visibility.[9]

The first true FLIR was built by Texas Instruments in 1964.[10] It consisted of a lens that focused IR signals on 180 helium cooled IR detectors. These detectors fed amplifiers that powered 180 light- emitting diodes. The image produced was shown on a cathode ray tube and was similar to a black and white TV picture.[11] As Texas Instruments was researching and developing these IR sensors in the late 1960's and early 1970's, the United States military was finding ways to put that technology to work.

Article Acronyms

FLIR - Forward Looking Infrared
FTU - Fighter Training Unit
HUD - Heads-up Display
IFTS - Internal Forward-Looking Infrared Targeting System
IR - Infrared
LANTIRN - Low Altitude Navigation and Targeting Infrared for Night
NVG - Night Vision Goggles
ORM - Operational Risk Management
TRAM - Target Recognition/Attack Multi-Sensor
UAE - United Arab Emirates
VC - Viet Cong

PAVE

In 1965, the Air Force was initiating development of a low-cost guided bomb capability for its aircraft. Aiding that effort, Texas Instruments conducted a series of tests at the Armament Development and Test Center at Eglin AFB, Florida. These tests incorporated laser technology to guide free falling ordnance. This classified project received the code name PAVE and was the beginning of what would later become a series of sensors and precision-guided munitions.

The original PAVE sensors were laser tracking and laser designating pods. PAVE ARROW, PAVE BLIND BAT, PAVE FIRE, PAVE GAT, and PAVE SWORD were early examples of the Air Force using laser technology in aircraft to find and destroy targets.[12] The PAVE KNIFE system, however, represented the first attempt by the Air Force to merge a targeting system with a laser designator as part of the same avionics. PAVE KNIFE or AN/AVQ-10 was carried on the inboard pylon of the F-4D. It had a stabilized bore-sighted TV camera and a laser designator. The TV camera incorporated a low-light system for night missions but was seldom used.[13]

Combat missions using the PAVE KNIFE system began in 1968 with the 8th Tactical Fighter Wing flying missions from Ubon, Thailand into Vietnam. However, the most famous mission of F-4's using PAVE KNIFE involved the targeting of the Paul Doumer Bridge, over the Red River, at Hanoi.[14] This bridge had been attacked numerous times with packages of 36 F-105s, on one occasion, and 50 F-105's on another. Those raids employed nonguided bombs, and successfully dropped spans of the bridge, but each time the bridge was repaired. On May 10, 1972, 8 F-4s with PAVE KNIFE and laser-guided bombs scored direct hits on a single span of the bridge.[15] This successful raid, using relatively few resources, *hooked* the United States military on this approach. The drive was now on to build better targeting systems in concert with more precise weapons.

The Air Force quickly improved upon the targeting features of PAVE KNIFE with the introduction of PAVE SPIKE (AN/AVQ-12), which was a smaller and lighter targeting pod also designed for carriage on the F-4. The Air Force purchased 156 of them from Westinghouse between 1974 and 1979.[16] Although PAVE SPIKE did incorporate new features of IR sensors and a laser range finder, this pod still had limited night capability.

The first real night attack capability came with the operational fielding of PAVE TACK (AN/AVQ-26), a targeting pod which was developed for use on F-4 and F-111 aircraft. Built by Ford Aerospace, the pod weighed 1,300 pounds.[17] Although not a true FLIR, in the sense that it did not provide night time scene detail looking from the front of the cockpit, PAVE TACK did provide a useful IR picture of ground reference points and targets. The pod had two fields of view, an environment control system, and a laser designator. PAVE TACK was a large sensor, carried internally on the F-111 and externally on the F-4.

At the end of the 1970s, the United States military introduced its first FLIR for an attack aircraft on the A-6E Intruder. The Target Recognition/Attack Multi-Sensor (TRAM) debuted in 1979. TRAM incorporated a chin turret with a FLIR, a laser designator, and a laser receiver.[18] TRAM was used for the delivery of unguided and guided munitions. The FLIR turret was gyro-stabilized and aligned with the laser, allowing the laser to precisely update target range just prior to unguided munitions delivery.[19] The gyro-stabilized FLIR allowed the weapon's system operator to precisely track the target after ordnance release for guided munitions delivery. This gave the A-6E the capability to maneuver after a weapon's release while at the same time continuing to guide the bomb.[20]

The combat capabilities of PAVE TACK and TRAM came to fruition with Operation El Dorado Canyon. In April 1986, following a terrorist bombing in Europe, the United States responded by attacking Libya's ability to support and conduct such terrorist activity. For the first time in history, the United States military possessed a robust armada of precision night attack aircraft, namely the A-6E Intruder with its TRAM capability, and the FB-111 with its internal PAVE TACK system.[21] A night attack was authorized for two distinct reasons. The first was that the Libyan MIG-25 pilots had a limited night time capability and would likely be unable to engage United States warplanes post-strike. The second was that the risk for collateral damage was minimized by striking at night because most of the civilian populace would be at home asleep. IR sensors onboard the strike aircraft, as well as laser-guided bombs, also contributed to minimizing collateral damage.

Using TRAM technology, the A-6Es evaded enemy surface-to-air missiles and antiaircraft artillery, destroyed their targets, and recovered safely home to their respective ships. FB-111s, flying at 150 meters and 834 kilometers per hour, employed GBU-10s (laser-guided 2,000 pound bombs).[22] Guiding these weapons with the PAVE TACK IR targeting and laser system, the first FB-111 dropped four bombs within 50 meters of the Libyan leader's headquarters.[23] Despite the loss of two American pilots, Operation El Dorado Canyon was a huge success. Tactical advantage and surprise were achieved by operating at night. IR sensors in military aircraft were now expected, and American industry would work hard to make the next generation of IR sensors even better than TRAM and PAVE TACK.

LANTIRN, F-16, NVGs and Future IR Targeting Systems

The F-16 entered operation in the United States Air Force in January 1979.[24] This single-seat, multi-role fighter was originally built to be a light weight, low-cost, daytime platform. The early versions, F-16A/B Blocks 5-20, saw gradual increases in engine performance and avionic capabilities. In the mid 1980s, the F-16C/D platform debuted with the Block 25, 30, and 32s. These versions incorporated newer radars than the F-16 A/B, as well as advances in HUD and engine capability. Toward the end of that decade, General Dynamics was ready to deliver a more advanced F-16, the Block 40.[25] This fighter, although very similar to early F-16s, was the first single-seat platform in the Air Force arsenal to become an air-to-air and air-to-ground, night-capable fighter. This essentially meant that the Block 40 could fight its way into a hostile area using radar missiles to engage air threats, and then employ precision laser-guided bombs to destroy ground threats, all under the cover of darkness. The system allowing this night employment was called LANTIRN or Low Altitude Navigation and Targeting Infra Red for Night.[26]

Also employed on the F-15E Strike Eagle, LANTIRN development began in 1980 at Martin Marietta's engineering facilities in Orlando, Florida.[27] Martin Marietta engineers began work on an external carriage system that allowed low altitude, night, all weather, precision attack. The LANTIRN system actually included two IR sensors—one for navigation and one for targeting. These sensors were located in two separate external pods. The AAQ-13 navigation pod housed a terrain-following radar in addition to its FLIR.[28] Unique to the F-16 Block 40, the navigation pod FLIR provided the first wide field of view for air-superiority fighters.[29]

The Block 40 had an expanded HUD and had the ability to superimpose the navigation pod's FLIR image through the HUD. The result was that the pilot was presented an IR image of the surrounding terrain as seen through the nose of the aircraft. The AAQ-14 targeting pod was used to identify and destroy ground targets by utilizing a FLIR and a laser designator to illuminate the target for laser-guided bomb deliveries.[30] The targeting pod worked in conjunction with laser-guided munitions much like the earlier PAVE TACK system on the F-4 and F-111. The IR picture of the target was presented to the pilot on a heads-down display along with crosshairs for aiming the laser.

At the time, LANTIRN provided the Air Force with a single-seat fighter capable of operating at night only a few hundred feet altitude under the protection of the navigation pod's terrain-following radar. The pilot was able to stay visual with his flight lead, even lights out, by flying in trail and referencing the FLIR through the HUD. Two F-16 Block 40s flying in this formation at night could actively search for air threats using their radar, stay visual with each other using the FLIR, stay protected in the low altitude environment using the terrain following radar, and drop precision-guided munitions on the target using the targeting pod. With the Block 40 LANTIRN system, advances in FLIR fighter capability had finally yielded a highly survivable, highly lethal, relatively low cost (as compared to the F-15E and FB-111), night-capable, single-seat fighter aircraft. The Air Force would take delivery of 265 F-16 Block 40s as the military conflicts of the 1990s loomed on the horizon.[31]

During Desert Storm, only the navigation pod was operational on the F-16. Military commanders still employed the Block 40 to ground targets. However, the F-16 achieved limited success. Trained for the bad weather scenarios in Europe, and against a Soviet threat, the Air Force now found itself able to work at higher altitudes away from certain ground threats while still dropping precision-guided ordnance. The Block 40s at the time attempted medium attitude unguided bombing referencing the FLIR for target acquisition. This did not enjoy nearly the success rate of the precision-guided delivery platforms.[32] The overall success of employing precision-guided munitions at night in the medium altitudes, however, would carry into Air Force doctrine after the conflict. The Air Force would continue to exploit its nighttime capability while at the same time reducing requirements to employ in the low altitude environment. The direct result was a decreasing need for LANTIRN's navigation pod as well as an increasing demand for the targeting pod.

From 1996 to 1997, the Air Force removed the operational need for F-16 Block 40 pilots to use the terrain-following radar. LANTIRN units then carried the navigation pod for its FLIR function only. However, due to FLIR's limited field of view, units gradually embraced NVGs. NVGs offered a higher degree of flexibility over the navigation pod. While the navigation pod showed a fixed FLIR image through the nose of the aircraft, NVGs were mounted to the pilot's helmet and could move as the helmet moved.

The Army had continued to advance night vision goggle technology and in the 1980's began fielding NVGs in their helicopters with great success.[33] The Air Force took notice, and by 1997, had incorporated NVG instruction into its training facility for the F-16 at Luke AFB, Arizona.[34] Using NVGs and targeting pods, the F-16 Block 40 from Aviano AB, Italy, saw combat in Bosnia and Kosovo. Shortly thereafter, all Block 40 units ceased flying with the navigation pod altogether.

The use of the combined two-pod LANTIRN system has become progressively more limited, although it is still available for foreign military sales.[35] However, IR targeting systems have become a fighter aircraft staple. F-16s, other than the Block 40, began to fly and employ with IR targeting pods. Air National Guard Block 25, 30, and 32 F-16s successfully incorporated Northrop Grumman's Litening Targeting Pod System. Litening had improvements over the Block 40 targeting pod that included a black and white TV tracker and improved IR resolution and close-in field of views.[36] Litening has successfully proven itself in Afghanistan and Iraq.

In an effort to further increase its IR targeting fighter capability, the Air Force is currently developing the third generation of FLIR pods. The Air Force now wants FLIR pods to operate at higher altitudes (up to 40,000 feet above mean sea level), and provide close resolution IR target detail from greater standoff ranges (up to 20 nautical miles slant range).[37] Companies who manufacture the newest IR pod include Raytheon's ATFLIR, Northrop Grumman's Litening II, and Lockheed Martin's Sniper pod.[38]

Currently, the Air Force and Air National Guard have selected the Sniper pod as an avionics update for the F-16.[39] Sniper offers a significant reduction in drag and weight compared to the Block 40 targeting pod. It also incorporates a third generation mid-wave FLIR, dual laser modes, a black and white TV tracker, a laser spot tracker, and a laser spot marker.[40] The Air Force started taking delivery of Sniper pods in 2003. The Sniper is expected to be the last external IR targeting system.[41] Future fighter jets such as the F-22 and Joint Strike Fighter will likely contain some type of internal targeting system.

IFTS and the Block 60

Even though IR targeting systems and NVGs have become the accepted baseline for fighters over the last decade, the navigation FLIR did not completely disappear. In 1987, Lockheed Martin conducted a series of test flights with a nose-mounted FLIR. This program was called Falcon Eye, and it incorporated a nose-mounted FLIR and a helmet-mounted display.[42] This revolutionary technology involved mounting a small FLIR on top of the radome of an F-16. The FLIR was slaved to movements of the pilot's helmet. The FLIR image was then projected into the visor of the helmet-mounted display. In essence, this allowed for truly turning night into day. Wherever the pilot looked, he could see a FLIR image of the surrounding terrain filling his visor.[43]

There are two notable aspects about the Falcon Eye program. First, mounting the FLIR on the top of the radome (just forward of the canopy), made the FLIR more in line with the pilot's actual head position. Second, using a FLIR-projected image in the visor meant that the sometimes cumbersome NVGs were not needed. In the late 1990s, a variation of the Falcon Eye program was incorporated into the latest F-16 to roll off the assembly line (the Block 60).

On 25 May 1999, the United States approved the United Arab Emirates (UAE) to buy 80 F-16 Block 60 aircraft. This was an $8B sale, with an additional $3B in research and development funded by the UAE.[44] Block 60 promises to deliver several new capabilities that current F-16s do not have. Some of the bigger advancements include the Block 60's conformal tanks (fuel tanks conforming to the fuselage above the wing to increase flying range), an agile beam radar with an electronically scanned antenna, and the Internal Forward-Looking Infrared Targeting System (IFTS).[45]

The IFTS appears similar to the Falcon Eye design. While IFTS does not incorporate a helmet mounted sight nor a FLIR slaved to the pilot's head movement, it does resemble Falcon Eye's nose mounted FLIR. Designated the AN/AAQ-32, the IFTS has both internal and external IR sensors. The navigation FLIR is a wide angle FLIR turret mounted just forward of the cockpit, and the targeting FLIR is an external sensor mounted underneath the engine intake.[46]

Hazards of F-16 Night Landings

A fighter training unit (FTU) is the third step in fighter pilot instruction. First, a student learns to aviate during a year of basic pilot training. Next, for those that will fly fighters, there are several months of advanced training introducing fighter tactics with less advanced platforms. For the F-16, the first time a new pilot operates this aircraft is at FTU. FTU training is generally separated into daytime takeoffs and landings and then into daytime tactics. Similarly, night training is separated into nighttime takeoffs and landings. Night tactics are subsequently introduced. The availability of the Block 60 IFTS for a student pilot's initial night sorties initiates consideration of including IFTS operation as part of their basic night landings.

To help understand the historical hazards of night operations in the F-16, five current instructors at the 162[d] Fighter Wing, Tucson Air National Guard were interviewed. These pilots were selected because of their previous experience with LANTIRN as well as their knowledge of teaching night landings at the Tucson FTU. Three questions were posed to each instructor. The were asked to describe:

- Local hazards for night landings in the F-16
- Use of the Block 40's navigation pod FLIR for taxi and landing
- Any F-16 night-landing mishap with which they were familiar

The following is a summary of F-16 night-landing mishaps learned from these interviews.

Four F-16 mishaps at night were detailed in these interviews. Two involved using the FLIR to help land and two did not. The first mishap described happened at an overseas base while landing at night. The approach was to the south, and just short of the runway was a valley with lower terrain than the landing surface. This created the illusion that the F-16 was high on glide path. The valley also produced a thick fog that crept up to the threshold of the runway and obscured visibility in the initial landing phase. With fog obscuring the landing zone, the pilot perceiving that the jet was above glide path, and no FLIR available to assist, the Air Force lost an F-16 when it crashed short of the runway.

A similar event happened at a continental United States F-16 base. The pilot was only able to get a few sorties prior to the event and was therefore not as proficient at night operations when the mishap occurred. On recovery to landing, the runway assigned was the opposite from the landing surface where the pilot was accustomed to landing. This particular runway had few city and other natural lights. This situation then created a black hole effect where the pilot had few visual cues to tell that he was descending. On this mishap, low proficiency, vectors to an unexpected runway, a black hole effect on short final, and no FLIR available to assist, all combined to produce a low situational awareness for the F-16 pilot. The result was a very hard landing followed by main landing gear failure.

The next two accounts involve emergency F-16 diverting to strange fields using the FLIR to assist. In the early 1990s, an F-16 flying a night low-level mission developed an engine oil problem. This particular low level was in Arizona, and the nearest divert for the pilot was the city of Kingman. Kingman's runway was not controlled at night and was a shorter-than-normal landing surface for the F-16. Using the F-16 navigational waypoints to find the airfield, the pilot then used the FLIR of the Block 40 to line up and land uneventfully on this short airfield. Further, the entire airfield was blacked out, with no lights on the runways or taxiways. A similar event also happened during an emergency divert due to an engine oil problem. This time, the aircraft was in Saudi Arabia on a night mission when the problem developed. The airfield chosen for divert was entirely blacked out, and the pilot successfully used the FLIR to line up and land uneventfully.

In each of these four accounts, the pilots involved were fully qualified in the F-16. None were beginners in an FTU environment. In the case of the fog landing, it is not certain if the runway threshold would have been adequately indicated on the display. The end result might have been the same. But in the case of the hard landing, utilization of a FLIR may have changed the outcome. At minimum, having the FLIR turned on would lessen the black hole effect on short final by providing an IR picture of the runway environment. Conversely, the FLIR could also have led to a low situational awareness because it is another sensor which must be turned on, adjusted, and cross-checked. In this case of low proficiency, adding another sensor only increases pilot workload and may be more of a distraction than a help. FLIR utilization then is not an overall solution to preventing night-landing mishaps in the F-16, but rather another tool that can be used to enhance situational awareness.

In trying to address whether or not utilization of the Block 60 FLIR should be applied at the FTU level for night landings, investigation into how the Block 40 FLIR was taught might provide some insights. As a former instructor at the LANTIRN FTU, one of the coauthors recalls how the navigation FLIR was introduced, and how it was used to assist in night landings. First, LANTIRN pods were withheld from the upgrading fighter pilot until that pilot was a graduate of FTU. Then, the new pilots going to Block 40 F-16 assignments were enrolled in a short top-off course to teach them the LANTIRN system. This course consisted of a week of academics to learn the systems and then 2 weeks of flying to accomplish four specific training missions. At the end of this course, the pilot was fully qualified to employ in the night medium altitudes using the LANTIRN systems. The pilot did not graduate from this program with a terrain-following radar qualification. To introduce the FLIR in flying operations, students were required to turn the FLIR on during ground operations, tune the FLIR to current atmospheric conditions, and observe the FLIR through both the heads-up display (HUD) and the heads-down display during taxi. The FLIR was turned down in the HUD for takeoff, turned back up for the mission, and turned back down for landing.

The reasons for turning the FLIR up and down in the HUD have to do with where the navigation pod was mounted, as well as the instructor pilot's ability to monitor (from the backseat) the student pilot's landing. The navigation pod was installed just abeam the bottom left side of the engine intake in the Block 40. Due to its proximity to the ground, this pod presented a distorted picture of the taxi speed when viewed from the HUD. When the FLIR was imposed in the HUD during taxi, the pilot erroneously sensed a much higher rate of movement across the ground during normal taxi speeds. As the upgrading pilot turned the FLIR down and not off in the HUD, he would no longer see the FLIR image superimposed, and therefore not obtain false ground rush features, while at the same time the instructor in the back would be able to call up the FLIR image in his heads-down display and would be able to monitor the student's progress.

Currently, the Air Force and Air National Guard have selected the Sniper pod as an avionics update for the F-16. Sniper offers a significant reduction in drag and weight compared to the Block 40 targeting pod.

This method was particularly useful for monitoring the student's landing at night. The student would fly his normal instrument approach until obtaining visual cues with the runway, consistent with FTU training without a FLIR. The instructor pilot, meanwhile, could watch the runway through the FLIR and confirm that the landing area was clear, quickly process the student's expected point of touchdown, and get a sense of aircraft height above the ground. All of these cues were invaluable for providing better instruction as well as increasing the safety aspect of monitoring the landing.

On the third ride in the program, the student was instructed to leave the FLIR up in the HUD on recovery and, in essence, conduct a FLIR-assisted landing. The underlying instructional concept was that by the third ride, the student was more comfortable operating the FLIR, was fairly current in night landings, and still had an instructor pilot in the backseat to quickly help if any problems arose. Once established on a precision approach final, from about 10 miles out and a few thousand feet in altitude, the student would look through the HUD with the FLIR up and attempt to identify the runway environment while primarily referencing the aircraft instruments. If the runway environment was not quickly identified, the teaching emphasis among instructors was to stay on the instruments and fly the approach. Most students could see the landing runway in the FLIR somewhere between 10 and 5 miles out from landing. Regardless of when, or even if, this FLIR ID happened, under no circumstances would the student be allowed to leave the FLIR up for the actual landing. The runway's green, red, and yellow visible lights coupled with the FLIR's IR depiction of the real lights created for a fairly bright HUD. In this situation, one of the first things to get overloaded was usually the pilot's depth perception. This potentially could lead to dangerous situations of a high flare, or an incomplete flare. Therefore, the FLIR was used to assist in finding the runway environment, but was never actually used in the landing phase.

Application of Operational Risk Management

One of the tools available to Air Force officers to assist them in safely integrating a new program is Operational Risk Management (ORM). ORM is a six-step process based upon four primary principles—accept no unnecessary risk, make risk decisions at the appropriate level, accept risk when benefits outweigh the costs, and integrate ORM into the planning stages of an operation.[47] Since the Block 60 had not yet arrived at the 162nd Fighting Wing at the time of this writing, the principle of placing ORM in the planning stages is met by conducting this analysis. The other three principles are addressed by a discussion of the steps as depicted below.

Based on this structured risk analysis, the recommended option is to introduce IFTS FLIR-assisted night landings during the student's second night sortie. This recommendation follows the logic that the student is already somewhat familiar with the IFTS from using it as a head's-down sensor during the day.

The first step is hazard identification. To assist in this step, interviews were conducted with 162d instructor pilots asking them to identify hazards for night landings in the F-16. One instructor indicated that the canopy glare from bright approach lights on Runway 11L at Tucson International Airport is a distraction, that the opposite runway, Runway 29R, has very little lighting, and that currently the 162d conducts many night landings with young students with very few cues available to the instructors for safely monitoring from the backseat. Three other instructors interviewed also mentioned a lack of approach lighting to Runway 29R at Tucson as being a potential hazard. In addition, it was indicated that using the IFTS FLIR could prove to be a distraction to the young pilot who is still trying to develop a non-FLIR normal sight picture for an F-16 night landing. Another potential hazard of the IFTS FLIR is that the young pilot could abandon cross-checking his aircraft instruments and rely solely on this visual picture. This hazard could include mistaking the landing surface for the parallel runway or taxiway, or getting dangerously low on final by not flying the instrument approach.

After reviewing the hazards, the next step concentrates on assessing the risk—that is, an aircraft could have a landing accident. There are four degrees of severity of risk using the ORM model: catastrophic, critical, moderate, and negligible.[48] Defining catastrophic as complete mission failure, death, or loss of system,[49] having a landing accident, at a minimum, results in the loss of that aircraft while it gets repaired. Therefore, the severity of this risk is categorized as catastrophic. Subsequently, a probability assessment is conducted. Night landing accidents occur very rarely, but all pilots are exposed to this risk. Following the ORM model, an unlikely probability coupled with a catastrophic severity yields an overall risk assessment of medium.[50]

The next ORM step, after accurately weighing the risk, is to seek methods to control that risk. The goal in this step is to find ways to reduce or eliminate the probability, severity, or exposure of the risk.[51] In this situation, the worst severity is already paired with the lowest probability. As previously mentioned, it is not likely given the nature of aircraft landing mishaps. Further, all FTU students are required to accomplish night qualifications. Thus, the risk exposure cannot be reduced. Therefore, the only adequate control measure is to attempt to reduce the severity of the risk. With regard to the hazards mentioned in Step One, having a FLIR available to the instructors in the backseat would actually remove some of the hazards. During an approach to Runway 29R, using a FLIR on final would lessen the effect of having few visual lighting cues prior to the runway threshold. In addition, the instructor would be able to monitor the student's landing more effectively by referencing the FLIR on the heads-down display.

Consideration must then be given to reducing risk by using the FLIR for the entire landing phase. Unlike the external Block 40 FLIR pod, which was never available to students during their basic FTU qualification, the Block 60 IFTS FLIR is internal and will be available for use on the student's very first sortie. This is important because, most likely, students will become somewhat familiar with the FLIR operation well before their first night sortie. Instructor pilots in the back seats of the first transition sorties will undoubtedly have the students at least turn on the FLIR. This is because having the FLIR up as a heads-down display in the rear cockpit will allow the instructor to better monitor the student's landing, even during the day. This leads back to the issue of allowing the student to leave the FLIR up in the HUD on his first night sortie.

There is precedence for landing with a FLIR, all the way through touchdown. The Air Force test community did just that with the Block 40 FLIR in the late 1980s. At Edwards AFB in the 1988-1989 timeframe, Air Force test pilots practiced landing at completely unlit airfields primarily referencing the FLIR. The landings were a fairly common occurrence and the teaching emphasis of new test pilots learning this technique was not to flare too high. Because of the low pod elevation, seeing an unlit runway in the HUD with the FLIR made the landing surface appear closer than it was in real life. Although there is no official basis as to why the technique was never incorporated in the FTU, practicality appears to be reason. Block 40 operational pilots never landed with the FLIR up in the HUD. They knew it was there if it was needed in an emergency, as in the two successful FLIR landings discussed earlier in this article, but it posed more of a risk than a benefit on routine night landings. Unlike at Edwards AFB, every approved airfield for F-16 operation at night is an instrument airfield with proper airfield lighting and an instrument approach. Having a FLIR up with normal runway lighting is likely to cause disorientation, as described earlier. Obviously, Air Force test pilots had the authorization as well as access to airfields where the lights could be turned off.

Although there is precedence for FLIR landings in the F-16, the benefits do not appear to outweigh the risk for the young pilot. Test pilots are carefully selected after years of flying their primary weapon system and have previously learned the proper sight picture of how to land at night. Student pilots in FTU have not yet learned that proper sight picture. To allow a student to integrate immediately with the IFTS FLIR at night is a failure of the FTU training program to ensure that the student has mastered the basic night landing flying skills. Using a FLIR in FTU will simultaneously reduce some risks and increase other risks associated with a night-landing mishap. The solution is most likely a compromise between when to use the FLIR and when to turn it off in the HUD. Those decisions are applied in the next ORM step.

Step Four of the ORM process is to make control decisions (for example, where the decision must be made as to which control course of action should be pursued).[52] Ultimately, this is where judgment is applied to see if the benefits outweigh the risks. In this case, the decision is where and how to integrate the FLIR into Block 60 night operations. If the Block 40 LANTIRN model is used, one option is for the upgrade student not to use the IFTS until the end of the basic program. By then, the student would have already had a few rides at night and would have made some landings without the use of a FLIR. The benefit here is that the student would first learn a non-FLIR-assisted landing sight picture and then build upon that sight picture later with the IFTS upgrade.

In comparison, student pilots in the previous UAE FTU course accomplished two night rides. The first ride consisted of night instrument approaches and landings and the second consisted of night air-to-air refueling, and then night intercepts. If the Block 40 model is adopted, these two rides would still be in the training flow. Extra rides would be added at the end of FTU to teach IFTS. In this case, there would be an increase in cost for the slightly longer course and the additional instructor pilot support required to teach the extra IFTS rides.

Another option is to introduce the IFTS during the basic FTU training program. In this case, the recommendation is to have the student's first night sortie be without using the FLIR. Here basic night instrument approaches and night landings would be emphasized. On the second sortie, fuel and time should be reserved for the end of the intercept mission to allow two instrument approaches. Once again following the Block 40 model, the emphasis should be placed on FLIR-assisted landings, using the FLIR to help identify the runway environment and then turning it down in the HUD for the actual landing.

If more advanced tactics are taught later in the program with the targeting IR portion of IFTS, then the FLIR-assisted landing sight picture could continue to be built upon. Both of these are sound options for reducing the risk of IFTS integration at the FTU level. The decision of which to follow will be influenced by the current unknown of how many additional night sorties are required to teach the full capability of IFTS. It is these authors' opinion that at least two additional night sorties will be required to teach the ground attack capabilities of IFTS. That would make a total of four night sorties required in the UAE FTU.

After choosing either option one or two above, the ORM process includes two final steps. These steps, however, are not addressed in this article since the Block 60 IFTS had not yet arrived on station at the time of writing. Once a night training plan is agreed upon by the leadership, and the jet is actually in place and conducting training sorties, then the next steps of implementing risk controls and supervising will be pertinent.

Conclusion and Recommendation

This article examined the history of IR sensors most influential to the F-16, and a pilot's perspective on the hazards of landing the F-16 at night. An Air Force ORM was then conducted as to the feasibility of integrating the Block 60 IFTS into an FTU environment. Based on this structured risk analysis, the recommended option is to introduce IFTS FLIR-assisted night landings during the student's second night sortie. This recommendation follows the logic that the student is already somewhat familiar with the IFTS from using it as a heads-down sensor during the day. On the second night sortie, it is recommended to have the student only use the FLIR to identify the runway environment and then to turn the FLIR down before actually touching down. This reduces the risks of having a night-landing mishap. Additionally, the student's first night sortie is recommended to be dedicated to standard night instruments and non-FLIR-assisted landings. This allows the emphasis to be on a night instrument cross-check and normal night visual landing cues, thereby giving the student a solid foundation to build his night habit patterns. If the intention becomes to teach an additional capability of IFTS, extra night sorties can be added toward the end of the training program. This recommendation safely incorporates the IFTS in the initial sorties, gives a solid night instrument background to the student, and gives the flexibility to build upon the student's IFTS procedures with additional IFTS night sorties later on in the program as dictated by the tactical requirement.

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notable quotes

Be nice to your mother but love your logisticians and communicators.

—Gen Charles A. Horner, USAF

You think out every possible development and decide on the way to deal with the situation created. One of these developments occurs; you put your plan in operation, and everyone says, "What genius…" whereas the credit is really due to the labor of preparation.

—Marshal of France Ferdinand Foch