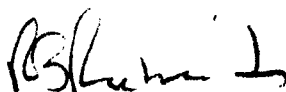


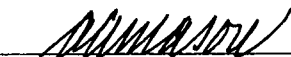
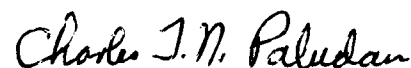
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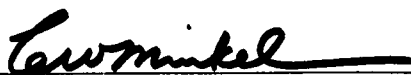


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A STUDY OF THE INTEGRATION OF THE
LANTIRN TARGETING SYSTEM ON THE F-14 TOMCAT

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Brian M. Kocher
December, 1994

DEDICATION

This thesis is dedicated to my wife Tori
who kept pointing out the light at the end of the tunnel.

ACKNOWLEDGMENTS

I would like to acknowledge my major professor, Mr. Bob Richards, for his guidance. I would like to thank my wife for her proof-reading and giving me a fresh perspective on my work. I would also like to thank Mr. Wes Quinlan, for his hard work and extraordinary engineering skills during the LANTIRN Integration program.

The conclusions and opinions expressed in this thesis are those of the author and do not represent the opinions or point of view of the United States Navy.

ABSTRACT

The United States Navy has begun efforts to integrate a precision targeting system onto the F-14 Tomcat to meet the Navy's precision ground attack requirements. As part of this effort, the Naval Air Warfare Center, Aircraft Division was tasked to conduct a preliminary analysis of the structural compatibility and integration feasibility of the Martin Marietta, Low Altitude Navigation Targeting Infra-Red for Night (LANTIRN) Targeting Forward Looking Infra-Red (TFLIR) pod on the F-14 Tomcat. Navy officials believe that a production TFLIR pod could simply be "bolted on", "plugged in" and "turned on" to give the Tomcat a full precision strike capability. The scope of the Navy's LANTIRN test program was limited accordingly to determine whether the pod would be structurally compatible within the F-14 flight envelope. The pod and aircraft were instrumented to collect vibration and acoustic load data as the aircraft was maneuvered throughout the F-14 flight envelope. Navy F-14 aircrew and Martin Marietta engineers formed a test team to study pod integration on the F-14 using a variety of integration methods. Although no analysis of the pod structure was conducted, it was presumed that if the vibro-acoustic load data measured on the F-14, were less than or equal to the loads previously measured on the F-15E, which currently carries the LANTIRN, then the pod would be assumed structurally compatible on the F-14. Though the Navy's program scope was focused on determining structural compatibility, the author was able to investigate several integration options and draw conclusions as to how best to integrate the system in the future. Within the guidelines of the test, the pod was determined to be structurally compatible, however, as the test was conducted using several integration options, numerous issues were raised which warranted further study before the pod could be considered fully compatible. Several pod mounting methods and station locations were studied to determine integration

effects on pod field of regard, pod-to-aircraft boresighting, resolution and performance. The results of this study concluded that the integration of the LANTIRN pod on the F-14's wing or fuselage station would result in an obscured field of regard which would limit aircraft maneuverability, increase exposure to hostile fire and may result in the loss of the F-14 during ground attack missions. The obscured field of regard is a major issue which should lead to the investigation of other integration locations. The integration methods which were evaluated, appeared to induce excessive boresight errors which would in turn make it difficult for aircrew to acquire targets prior to weapon release. Though quantitative analysis of the pod's resolution and performance appeared satisfactory, all tests were conducted against large, fixed targets of known position and further study should be conducted using small, mobile targets while actually conducting PGM delivery, to further determine the suitability of the different methods of integration.

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BACKGROUND

During Operation Desert Storm, the United States Armed Forces demonstrated that delivering precision guided munitions (PGMs) from aircraft, was critical in destroying enemy targets deep in Iraqi territory. This capability allowed U.S. aircrew to precisely deliver ordnance, at stand-off ranges, against military targets while minimizing civilian casualties and reducing exposure to hostile surface-to-air missiles (SAM) and anti-aircraft artillery (AAA). The sensors used by aircrew also allowed man-in-the-loop confirmation of the target under attack and increased the accuracy of battle damage assessment (BDA)- determination of how complete a target was destroyed- which reduced the number of required sorties. Although maintaining a deep strike capability is of utmost importance, the Navy is under fiscal pressure to reduce the size and cost of its forces. To reach budget and force structure goals, the US. Navy's current plan is to retire its only deep strike capable aircraft, the A-6E, by 1996. However, the Navy's newest fighter, the F-18E/F, is currently under development and will not be in production soon enough to maintain a continuous deep strike capability. These factors will leave a gap in the Navy's all-weather, long-range, precision ground attack capability unless the Navy makes quick modification to other existing aircraft; so the Navy is investigating possible modifications to the F-14 Tomcat. The Navy is considering various options such as the addition of a Forward Looking Infra-Red (FLIR) targeting system and Laser Designator (LD). The incorporation of a FLIR/LD will give the F-14 an on-board capability to detect, identify and attack ground targets day or night and strike them with PGMs. Navy officials believe the fastest way to provide the F-14 a precision capability is to procure a system "off-the-shelf", which

would hopefully mean no development cost or time delays. One such off-the-shelf system is the Low Altitude Navigation and Targeting Infra-Red Night (LANTIRN) Targeting FLIR (TFLIR), currently in operation on the US. Air Force's F-16 and F-15E aircraft. The Naval Air Warfare Center, Aircraft Division (NAWC AD), at NAS Patuxent River, Md., was tasked to conduct a preliminary flight test to determine the structural compatibility of the LANTIRN with the F-14 flight envelope. In addition NAWC AD was tasked to demonstrate the feasibility of integrating the system on the aircraft and assess its capability to conduct precision ground attack missions. While it sounds simple, integrating a targeting FLIR onto a tactical aircraft, requires careful consideration of the pod's placement, mounting method and the ability to fully utilize the pod's capability with the aircraft's avionics. Just because a TFLIR demonstrates structural capability does not guarantee it has been integrated in a manner which optimizes the pod's performance capability.

PURPOSE

The purpose of the Navy's test program was to answer the question whether the pod would sustain the loads expected throughout the F-14's operating envelope. Since the F-14 is capable of sustaining high mach numbers and load factors (g's) and vibration loads have never been measured, the study will provide insight into ways to optimize TFLIR integration and may further be applicable to other systems considered for future integration. The author was tasked, as the Project Officer, to plan the integration test during which several questions were raised concerning pod placement and mounting. The scope of the Navy test program was restricted to establishing structural compatibility but based on the issues raised during the test, this thesis will also discuss the effects of different mounting methods and positions on pod performance and mission capability. While flying the test flights, the author's goal was to collect data and determine how pod placement and its mounting can be optimized to maximize pod performance. Where a TFLIR is placed on the F-14 will determine the overall field of regard which must be maximized to ensure that full aircraft maneuverability. How the pod is integrated on the aircraft will determine the boresight tolerance and whether the FLIR imagery is degraded due to vibration. How and where the pod is integrated also affects the aircraft's capability to carry other stores and this aspect was also studied to determine the optimum pod location. Each technical aspect of a TFLIR pod's integration will be discussed with respect to its effects on the air-to-ground mission.

AIRCRAFT DESCRIPTION

THE TEST AIRCRAFT

The F-14 Tomcat used for this study (bureau number 161623, side number SD220), shown in appendix B, figure 1, was a two seat, twin engine, supersonic air-superiority fighter, manufactured in the early 1970's, by the Grumman Aerospace Corporation. The aircraft was designed to accommodate a crew of two. The pilot, seated in the front seat had primary aircraft control but had no control of the aircraft's radar, Television Camera Set (TCS) or Infra-Red Search and Track Set (IRSTS). The Radar Intercept Officer (RIO), seated in the rear cockpit, controlled all the above aircraft sensors and also had primary control over most of the aircraft's avionics. In addition to its primary air superiority role, the aircraft was designed for fleet air defense (FAD) and air-to-ground (A/G) attack missions. Though the aircraft was designed to perform A/G functions, the capability had never been demonstrated until 1990 when the first operational squadron began training for unguided bomb delivery. The test aircraft was a unique platform which combined the airframe and engine components of an F-14A with the digital avionics suite of the F-14D. The test aircraft was given the designation of F-14D(minus). It was powered by two Pratt and Whitney TF-30-P-414A dual axial flow compressor turbo-fan engines equipped with an afterburner (AB) for thrust augmentation. The installed engine thrust at military and maximum afterburner was 10,875 and 17,077 pounds, respectively. The F-14 featured variable sweep wings which could be positioned from 20 to 68 degrees and were automatically programmed as a function of mach number, measured from the pilot's pitot static system. The aircraft was designed to carry AIM-54, AIM-7 and AIM-9 missiles and external stores

from eight hard-point stations on the center fuselage between the nacelles and under the nacelles and wing glove; stores could not be carried on the movable portions of the wing. The nacelle stations (stations 2 and 7) were designed to be configured with only external 2,000 lb. fuel tanks. All stations are shown in appendix B, figure 2. The zero fuel and stores gross weight was approximately 43,735 lbs which included trapped fuel, oil, gun and pylons. The test aircraft was not production representative because of the unique combining of F-14D avionics into an F-14A airframe but this enhanced the validity of the study. Since the airframe was production representative of the F-14A, the air loads and vibrations measured at the pod are expected to be representative. The TCS and IRSTS were not installed during this test program. A complete description of the F-14A airframe and engines can be found in the Naval Air Training and Operating Procedures Standardization (NATOPS) Flight Manual, reference 1.

SINGLE CHIN POD

The F-14A (and B) aircraft version of the Tomcat was designed with a Single Chin Pod (SCP), shown in appendix B, figure 3, mounted under the nose of the aircraft which provided external housing for the Television Camera Set (TCS). The test aircraft was equipped with a SCP during several flights to approximate the F-14A airframe configuration and generate F-14A/B representative airflow, acoustic and vibration loads.

DUAL CHIN POD

The F-14D version of the Tomcat was designed with a Dual Chin Pod (DCP) configuration to provide external housing for the Television Camera Set (TCS) and the Infra-Red Search and Track Set (IRSTS). The DCP was substantially larger than the SCP and its larger frontal area was expected to generate different flow characteristic in the fuselage area. Martin Marietta Engineers were anxious to configure the test aircraft with the DCP as it was postulated it would generate the worst case loads on the LANTIRN pod. The test aircraft was subsequently equipped with the dual chin pod, shown in appendix B, figure 4 to approximate the F-14D airframe configuration and generate representative F-14D airflow and ensuing acoustic and vibration loads.

AIRCRAFT VARIATIONS

Since the primary purpose of the Navy test was to measure vibration and acoustic loads, it is important to understand the differences between the test aircraft and the different versions of the F-14 and how these variations might affect the loads experienced by the LANTIRN pod. It is also important to point out the avionics variations to understand how final integration might be accomplished. The Navy currently has the F-14A, B and D versions of the Tomcat in its inventory, each with widely different airframe, engine and avionics configurations. All F-14 versions are restricted to the same operating envelope, shown in table I. The test aircraft was essentially an F-14A airframe with the TF-30 engines but it was configurable with either the dual or single chin pod as testing required.

Table I
F-14A, B AND D OPERATING ENVELOPE

PARAMETER	LIMITS
ALTITUDE	43,000 FT MSL MAX.
AIRSPEED	680 KIAS MAX. ¹
MACH	1.88 IMN MAX.
LOAD FACTOR	-2.4 TO +6.5 G

Note 1: Airspeed is dependent on store loading. Maximum airspeed is with external tanks, store on station 3, 6 and wing pylons. No published limit is provide with LANTIRN installed however its size and weight is approximately equivalent to an AIM-54 missile.

To date, the Navy has not finalized the configuration of the precision strike capable Tomcat therefore testing all aircraft configurations would increase the applicability of the results.

F-14A

The F-14A variant was the first and consequently the oldest version of the Tomcat. It was equipped with a single chin pod, TF-30 engines, analog avionics and magnetic tape read memory. The LANTIRN test team was asked the question, "what would it take to integrate the LANTIRN onto the F-14 if we had to go to war in six months?" The answer was not clear cut since integration would require reducing current F-14 capabilities. Martin Marietta conducted an in-depth analysis and determined that since the F-14A has no digital architecture, control of the LANTIRN would have to be accomplished by substituting the pod's functions for existing radar or TCS controls. F-

14A avionics did not support integrating the pod so the idea to add a LANTIRN control panel was presented. A control panel was used during this study to investigate this concept of integration. The primary display available in the F-14A was the Tactical Information Display (TID), which was a round, 8" diameter Cathode Ray Tube (CRT) green monochrome display. It was determined, by Martin Marietta engineers, that the TID would be compatible but to integrate the FLIR video through this display would still require an additional display processor. This would require further development and therefore could not be evaluated during this study.

F-14B

The difference between the F-14A and F-14B was primarily in the engines. In the F-14B, the TF-30's were replaced with the more reliable, higher thrust, GE-F110 engines. It was postulated that the F110 engines might create different acoustic and vibration loads particularly with the pod loaded in a fuselage station. The difference in loads would be probably be noticed in the high frequency vibrations which would have the greatest affect on FLIR resolution and image display performance, not on the pod's structural integrity. In addition, the higher thrust of the F110's enable the F-14B to sustain higher speeds and load factors (g's) than the F-14A. Although all F-14's are limited to 6.5g, the F-14B is capable of sustaining these loads for longer periods than the F-14A. With respect to this study, the avionics suite of the F-14B is identical to the avionics of the F-14A.

F-14D

The F-14D represented a dramatic upgrade of the Tomcat's avionics suite which included a modern, digital MIL-STD-1553B digital bus architecture, 4" square multi-function displays, additional sensors and Hands Off Throttles and Stick (HOTAS) controls for both the pilot and RIO. The F-14D was also equipped with the GE-F110 engines for improved performance. The key airframe difference is the addition of the dual chin pod. One goal of this study was to quantify any differences in vibration loads which might be attributed to the larger dual chin pod.

AVIONICS

The test aircraft was a combination of the F-14A airframe and engines with the avionics of the F-14D. The aircraft was equipped with two AN/AYK-14 (XN-6) tactical mission computers sets (MCS). The mission computers interfaced with aircraft avionics and displays through a dual channel MIL-STD-1553B data bus. The MCS were configured with software load D01.5 which did not include an air-to-ground radar mapping capability. The F-14's front and rear cockpits, shown in Appendix B, figures 5 and 6, featured several displays including three multi-function displays (MFDs), a TID, a Horizontal Situation Indicator (HSI) and the pilot's Heads Up Display (HUD). These displays were controlled by two independent Display Processors (DP). Two MFDs in the front cockpit and one in the rear allowed the aircrew to view FLIR image video and monitor FLIR system status. The LANTIRN TFLIR pod was not integrated through the 1553B MUX bus during this study, rather, the pod video was hard-wired to the MFD through one of the DPs, using standard RS170 video compatible coaxial cable. This limited integration did not allow the aircrew to control the pod through the

Hand Control Unit (HCU) or change display functions through the MFD pushbuttons. Though this integration did prevent full pod evaluation, it did allow the evaluator to observe FLIR video. A complete description of the F-14D avionics can be found in the F-14D NATOPS Flight Manual, reference 2.

MIL-STD-1553B DATA BUS

The 1553 data bus was a two channel, twisted wire pair designed to provide a digital interface for aircraft avionics. The F-14D used six different buses, the primary bus of concern to this study being the avionics bus. The avionics bus provided the interface between the primary (mission computer 1) and secondary (mission computer 2) computers, display processors, the hand control unit and the sensor control panel. The armament bus provided the aircrew digital interfacing between the mission computers and each store station, through the Stores Management Set (SMS) which also functioned as the armament bus controller.

AIM-54 WEAPONS RAIL

One important aspect of this study was the use of existing production hardware for pod integration. This was intended to further reduce the amount of hardware development. The F-14 aircraft used a system of weapons rails and adapters to carry stores on the fuselage of the airplane. The suspension equipment, shown in appendix B, figure 7 consisted of a weapons rail, an ADU-703 adapter unit and a BRU-32 bomb rack. These items were attached to the fuselage, between the engine nacelles, to form the parent store stations. The weapons rails were developed and manufactured by

Grumman Aerospace Corporation, weighed 500 lbs, and were designed to facilitate the carriage of AIM-54 air-to-air (A/A) missiles and A/G weapons on aircraft stations three, four, five and six (fuselage stations). These rails served as the structural interface between the airplane and the ADU-703 adapters.

ADU-703A/A ADAPTER

The ADU-703 adapter, shown in appendix B, figure 8, was the interface between the BRU-32/A bomb rack and AIM-54 weapons rail. The ADU-703 was developed by the Naval Air Warfare Center, and was designed to provide a universal interface between the AIM-54 weapons rail and other standard Navy weapon rack assemblies. It was 80.0 inches long and weighed approximately 100 pounds. The adapter was installed in the weapons rail with four bolts and was equipped with electrical wiring and an umbilical connector to direct the 28 volt DC firing pulse to the BRU-32/A bomb rack. The ADU-703A/A used for this test was the production configuration and was rated for carriage of all F-14 NATOPS approved stores up to the flight limits of the basic aircraft (LBA).

BRU-32/A EJECTOR RACK

The BRU-32/A, shown in appendix B figure 9, was the parent bomb rack used to carry A/G stores on the F-14 aircraft. It had 14 and 30 inch suspension hooks and featured safety interlocks to prevent inadvertent stores release on deck. The BRU-32/A also was designed to provide automatic sway brace tightening to remove any excessive store motion in-flight which could result in inadvertent store release or possible bomb to

aircraft impact during release. Tightening was accomplished by four sway brace feet which were designed to automatically tighten as a store was rocked back and forth. The effectiveness of the sway brace feet to automatically tighten was in question prior to this study. Throughout operational use, these feet had demonstrated marginal capability to automatically tighten with 500 lb. general purpose bombs loaded and it was initially suspected they would not provide sufficient tightening of the LANTIRN pod either. The primary ejection unit was designed to use two CC-45 cartridges to generate the required gas pressure for store ejection and release operation. The BRU-32/A's used for this test were not equipped with CC-45 as the LANTIRN pod, at a unit cost of \$2.3 million, was identified as not jettisonable. The auxiliary release unit used one MK 19 cartridge which was designed to open the hooks and allow the weapon to free fall. Here again, the MK 19 cartridge was not installed to prevent inadvertent pod release. The BRU-32/A was designed with nose and tail solenoids to provide arming mode selection. Three positive arm latches, forward, center and aft, were also provided to positively arm weapons or fins. The BRU-32/A was a production version and it weighed 76 pounds.

ADU-703 LANTIRN ADAPTER (MMTI ADAPTER)

The LANTIRN pod was designed to mount directly on F-16 and F-15E hardpoints and would require specially designed hardware to mount the pod on an F-14 store station. To meet this requirement, Martin Marietta designed and built an adapter which would interface with the ADU-703. The ADU-703 LANTIRN adapter, shown in appendix B, figure 10, was designed as a rigid pod mounting structure which can be mounted in place of the BRU-32/A. Understanding the need for rigid pod mounting, the ADU-703

LANTIRN adapter was designed to decrease the amount of pod movement relative to the aircraft by providing a single, solid mounting interface. The adapter was designed and manufactured by Martin Marietta specifically for this test program.

BRU-32 BOMB RACK PYLON

Mission flexibility is a critical feature of Navy carrier aircraft and to increase the F-14's capability, a means to integrate the pod without changing hardware and reconfiguring aircraft was investigated. If the pod could be mounted directly on a production BRU-32 bomb rack, the pod could quickly be mounted or removed on the flight deck. Martin Marietta designed and built a hard-back, type adapter, called the BRU-32 Universal adapter, which bolted on the back of the LANTIRN pod to provide it with standard 14 or 30 inch suspension lugs. The BRU-32 Universal adapter, shown in appendix B, figure 11, was designed to provide a mounting interface between the pod and the BRU-32 ejector rack. The adapter was designed to create a solid mating structure and allow for correct mating to the BRU-32. The BRU-32 Universal Adapter was designed to allow TFLIR integration on the F-14 without changing existing F-14 hardware and allow pod integration on any store station.

HIGH ANTI-RADIATION MISSILE (HARM) ADAPTER ASSEMBLY

The F-14 is not capable of carrying stores, other than air-to-air missiles, on the wing stations so to evaluate the pod on these stations required additional hardware. During a previous program, the Navy developed the HARM adapter which is compatible with the ADU-703 and BRU-32. The HARM adapter was no longer in production but was

acquired to allow LANTIRN testing on the F-14 wing station. The HARM adapter assembly, shown in appendix B, figure 12, was originally designed to provide an interface for the HARM on the F-14 wing pylons. For this test it was used to interface with both the ADU-703 LANTIRN adapter and also the BRU-32 Universal adapter combination when the pod was mounted on the F-14 wing pylon.

GBU-10 BOMB UNIT

The purpose of integrating the LANTIRN on the F-14 was to give the aircraft the capability to guide precision weapons such as the Guided Bomb Unit (GBU) series of Laser Guided Bombs (LGB). GBU's range in size from the 1,000 lb. GBU-16 to the 2,700 lb. GBU-24 "Bunker Buster". The most common and mission capable is the 2,000 lb. GBU 10. The GBU-10, shown in appendix B, figure 13, was comprised of a MK 84, 2,000 lb. general purpose bomb body, a MAU-169 Computer Controlled Guidance Unit (CCG) and a MXU-667 wing assembly. Total weight of the bomb was 2083 lbs. The CCG and guidance fins were mounted on a forward adapter assembly on the front of the bomb and was designed to provide target detection and laser weapon guidance. The wing assembly was mounted aft and the folding wings were designed to extend upon release from the aircraft. The guidance fins were attached to the CCG to control direction of flight of the weapon as it glided toward the target.

LANTIRN TFLIR POD DESCRIPTION

GENERAL

The LANTIRN TFLIR is a podded, passive IR detection system which allows the aircrew to operate without generating tell-tale emissions which could provide information to the enemy concerning the aircraft's location and mission. The high resolution of an IR sensor provides improved pointing accuracy and target position determination in addition to greater target information provided in a "picture-like" image. The FLIR detection system allows attack aircraft to operate unrestricted in day or night conditions and increases its capability to operate in less than optimum weather conditions. Two major limitations of the FLIR detector are its susceptibility to boresighting errors and degradation to image resolution. After all, the two primary purposes of a FLIR targeting system are to find targets and then accurately deliver ordnance against it. As was reinforced during Operation Desert Storm, a FLIR's performance is directly dependent upon atmospheric conditions. Iraqi forces were successful in reducing US night attack effectiveness by generating tremendous amounts of atmospheric interference in the form of smoke, which they generated by setting oil wells on fire. In addition, the Iraqis learned that by scattering smaller fires throughout the battle field they could successfully mask armored tanks and artillery pieces and increase aircrew targeting difficulty. To counter these defensive tactics, it is important that a FLIR be properly integrated to minimize sources for system degradation which are aircraft induced. The detection range of a FLIR is limited by the line of sight propagation which is determined by the level of natural and man-made clutter and noise generated in the infra-red region. This interference takes the form of clouds, dust and

smoke which decreases system performance by inducing absorption and scattering losses in the target image. These are aspects which cannot be controlled and a systems ability to reduce these losses is predetermined by its design. Other sources which affect FLIR performance are related directly to its integration on an aircraft and are the focus of this study. Proper boresighting, sufficiently rigid mounting and pod location affect the FLIR's ability to detect, acquire and maintain target illumination while maintaining the necessary precision. This study uses several integration method and mounting locations to further understand the impact on FLIR performance and mission capability.

PHYSICAL CHARACTERISTICS

The LANTIRN Targeting Pod, serial #10243, shown in appendix B, figure 14, was designed by Martin Marietta Technologies Incorporated (MMTI), for integration onto the F-16 Fighting Falcon and later for the F-15E Strike Eagle; both currently deployed by the United States Air Force. The test article was a USAF production system except it was not tested with the laser designator system installed. The pod skin structure and internal mounting racks were made of aluminum alloy. The pod physical characteristics are shown in Table II.

Table II
PHYSICAL CHARACTERISTICS
OF THE LANTIRN TFLIR

PARAMETER	VALUE
Length (in)	98.5
Diameter (in)	15.0
Weight (lb.)	540
CG (Pod Station-in)	49.3
I-roll (lb.-in ²)	14,600
I-pitch (lb.-in ²)	447,000
I-yaw (lb.-in ²)	448,000

Though originally developed for the F-16, the LANTIRN TFLIR was also designed for simple integration on any single or two-seat aircraft equipped with the MIL-STD-1553B data bus. The pod was designed to provide day or night precision delivery of conventional, laser-guided bomb (LGB) and IR weapons (Maverick). The principal functions of the targeting pod were to allow the aircrew to automatically acquire and laser designate target tracks for LGB delivery. The TFLIR pod was divided into three major sections; nose, center and aft. The TFLIR was designed with flexible functionality to meet the mission capabilities required in both single and dual-seat aircraft. Primary designed functions included dual field of view (FOV), automatic and manual slewing. The pod was also designed with several target tracking modes. For this test, the F-14D(minus) was equipped with a non-production targeting pod control panel mounted in the aft cockpit. A complete description of the LANTIRN TFLIR pod is found in the System Description Document for the LANTIRN Targeting Pod, reference 3.

TARGETING POD CONTROL PANEL

Since the pod was not integrated through the 1553 bus, a special targeting pod control panel was developed. Navy officials speculated and hoped that this limited pod controllability was all that was required to use the pod effectively, however, experienced operators expressed concern with this integration approach. The study hoped to determine, one way or the other, the viability of such a limited integration while further determining other needed functional capabilities. The targeting pod control panel, shown in appendix B, figure 15, was designed and built by Martin Marietta and was located in the rear cockpit, right-hand console. The panel allowed the Radar Intercept Officer (RIO) to control a few basic pod functions. Pod functions provided through the panel were pod power, turret stow and unstow, a pod overtemp indication, FOV selection, Initiated Built-In Test (IBIT) and pod elevation Line of Sight (LOS) selection. Pod elevation LOS was limited to five preset depression angles measured from the pod reference line: 0, -2.5, -12, -25 and -55 degrees. Changing pod LOS depression angle was accomplished by depressing the CHANGE LOS push-button for greater than .25 seconds but less than 2 seconds. After each successive depression, the pod would slew to the next depression angle and upon reaching -55 degrees, return to 0 degrees. Selecting the CHANGE LOS push-button for greater than 2 seconds commanded the pod to AREA TRACK.

NOSE SECTION

The nose section, shown in appendix B, figure 16, was designed to house the TFLIR optics, IR sensor and the laser transmitter/receiver and also contained the gimbaled steering assemblies. The front shroud portion was designed to support the TFLIR

turret, which moved in pitch and housed the stabilized optics for the FLIR and the Laser Designator/Ranger (LD/R). The turret was equipped with two windows, the large lower window for the FLIR, while the upper window was designed for the LD/R. The rear portion of the nose section housed the target acquisition FLIR and was designed to provide unrestricted roll motion for the FLIR optics.

GIMBAL ASSEMBLIES

The TFLIR gimbal assemblies were designed to maximize the system's field of regard (FOR), LOS slew rates and provide a stabilized pod track during high aircraft accelerations (g's) and body rates. The gimbal assemblies, shown in appendix B, figure 17, consisted of inner, middle and outer structures which provide, respectively, for TFLIR LOS motion in yaw, pitch and roll. Pod designed gimbal drive limits are shown in Table III.

Table III
LANTIRN TFLIR POD
GIMBAL DRIVE LIMITS

GIMBAL RATE LIMITS	rad/sec
Pitch	1.4
Yaw	.5
Roll	5
Deroll	5.5
GIMBAL ACCELERATION LIMITS	rad/sec²
Pitch	14
Yaw	14
Roll	48
Deroll	48
GIMBAL ANGLE LIMITS	degrees
Pitch	+35, -235
Yaw	+5.0
Roll	Unlimited
Deroll	Unlimited

This inertial platform was designed to isolate the LOS steering from aircraft rotational dynamics, making the target acquisition and tracking task less demanding. By stabilizing the image, the aircrew could observe the target upright and stationary, as if it were being viewed through a window, regardless of the aircraft's attitude and position relative to the target. Other FLIRs, for example the A-6E FLIR system, used aircraft stabilized systems which resulted in the target sometimes being present upside-down at certain aircraft attitudes. This was disorienting to the aircrew and made it difficult to reposition the FLIR cursor since inverting the target image causes a reversal in the operative sense of the FLIR control. Since the pod was tested with a limited integration, the pod was stabilized relative to the aircraft axes. This limited integration

also resulted in the FLIR image orientation changing whenever the aircraft was maneuvered. Since the pod LOS was fixed at one of the selected elevation angles, and could not be slewed manually, the pilot had to maneuver the aircraft to point the pod whenever pointing at a specific reference point was required.

FLIR STABILIZATION

The TFLIR was designed to provide horizon-stabilized imagery during target tracking regardless of the attitude of the aircraft. While tracking, the FLIR was designed to maintain target lock during LOS rates due to aircraft/target relative motion of up to 75 degrees/second without degrading the accuracy of the system. The FLIR was designed to provide stabilization less than 30 microradians in narrow FOV (NFOV) and less than 150 microradians in wide FOV (WFOV). Therefore as the aircraft were maneuvered, the FLIR would remain pointed at the intended targeting location, particularly during LGB delivery when precision is critical.

FLIR FIELD OF VIEW

The FLIR Field of View (FOV) is the instantaneous extent of the line-of-sight positions at which the sensor can detect IR energy at a given time. The FOV is a design characteristic which further drives boresight requirements and determines the aircrew's workload for target acquisition. Relative to an air-to-ground mapping radar, FLIR's have a short detection range and are not used for initial target detection. Similarly, aircrew are usually provided with preplanned target location information which allows them to drop a waypoint (inputting the target's latitude and longitude) in the aircraft's

Inertial Navigation System (INS). Transitioning from an INS waypoint or radar target -- called a FLIR hand-off -- requires the FLIR LOS be slaved to one of these sources for initial pointing. Assuming there are no INS drift errors and the waypoint coordinates are accurate (which is a pretty big assumption), the FLIR's field of view size and the system boresight accuracy then determine whether the target will be displayed to the aircrew. If the target is not within the field of view the aircrew must manually slew the FLIR in search of the target which delays or prevents target acquisition. The LANTIRN was designed with two field of view selections: Narrow FOV (NFOV) of 1.69×1.69 degrees and Wide FOV (WFOV) of 5.97×5.97 degrees. NFOV functions to increase target detection range and is therefore selected during initial target acquisition. If initial target detection for a tank size target, is expected to occur at 8 NM slant range, with the aircraft at 15,000 ft AGL, then the target must be within the FLIR spot size depicted in figure 1, for the aircrew to detect it.

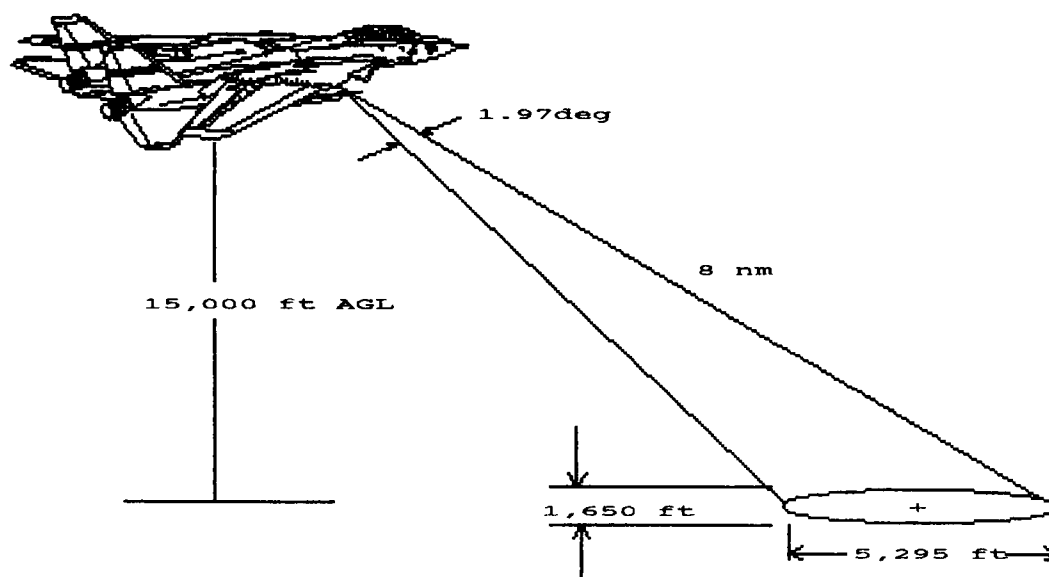


Figure 1
FLIR FIELD OF VIEW SPOT SIZE DEPICTION

The aircraft altitude affects FLIR FOV such that as altitude is decreased, the spot size increases as the FLIR graze angle becomes smaller. Aircraft altitude is dictated, however, by preplanned weapon release conditions and tactics.

FLIR FIELD OF REGARD

FLIR field of regard is an important aspects of FLIR integration that is widely overlooked. It is necessary to place the FLIR optics in a location that is relatively unobstructed by airframe components and stores to prevent inadvertent laser masking or loss of target tracking. Standing alone, the LANTIRN TFLIR was designed to permit full spherical steering of the sight line. The designed TFLIR FOR is shown in appendix B, figure 18. Because of physical design limitations, the FLIR LOS was mechanically obscured by the FLIR housing at ± 150 degrees pitch but combined with the FLIR's designed unrestricted roll capability could provide a designed field of regard of a full sphere minus a 30 degree half angle cone aft. When mounted on the aircraft the FLIR must now account for the aircraft components during FLIR and LD operation. Knowing the masking limits of the aircraft is necessary to automatically inhibit laser operation when the FLIR reaches these limits. The pod was designed to store an aircraft masking table, which was dependent on the aircraft type carrying the pod. By preprogramming the FLIR it was designed to automatically inhibit laser operation unless the LOS was clear. Since no such table was available for the F-14, F-15E masking tables were used for this study. As the FLIR LOS approached the masking limits, pod symbology would flash to warn the aircrew of impending masking and allow them to maneuver the aircraft to prevent it. Since the laser was not installed in the test pod, the aircrew only noted the flashing symbology. Maximizing the FOR

was important to ensure the pilot could conduct necessary maneuvers without obscuring the target with components of the aircraft. Typical aircraft maneuvers during LGB delivery is shown in figure 2.

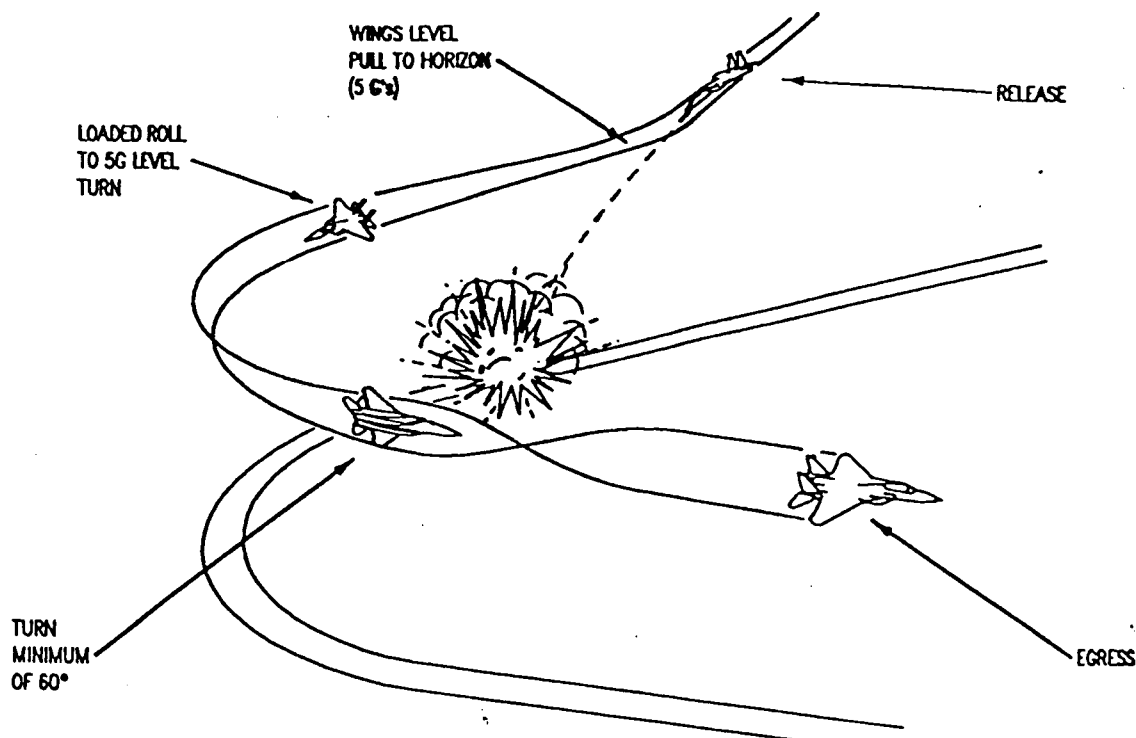


Figure 2
F-14 MANEUVERS DURING LGB DELIVERY

TARGET TRACKING

FLIR automatic tracking functions are necessary to hold the laser spot on the intended target as well as assist the aircrew in designating the correct target. During ingress to the target area, the aircrew will initially slave the TFLIR to an approximate target location; usually a waypoint or radar target. As the target comes into the FLIR field of view and the aircrew can recognize it, they will manually position the cursor to the

optimum aimpoint on the target -- this is referred to as sweetening. After sweetening the cursor position, the aircrew will select a tracking mode to automatically maintain cursor positioning over the aimpoint. Each track mode has limitations so the best track mode must be selected based on the aircrew's assessment of the environment and situation. For example, a rate stabilized tracker is suitable for moving targets particularly in the presence of other potential objects, such as buildings and trees, which may temporarily mask the target. A rate stabilized tracker memorizes the target's rate of motion and when the target is temporarily masked from view, the tracker will continue to reposition the FLIR along the target's predicted path. The targeting pod tracking system was designed to track ground targets automatically with accuracy sufficient for laser guided weapon delivery. To accomplish this, the pod was designed to track correlate using two independent point trackers. The pod tracker was designed to provide the operator with a stabilized scene and minimize aircrew workload during track operations. The LANTIRN's designed target tracking characteristics were as follows:

1. Track a tank size target at $> 30,000$ feet (0.3 by 0.3 milliradians).
2. Acquire and track a tank size target under the following conditions:
 - a. Atmospheric attenuation coefficient (8-12 microns) 0.2 km^{-1}
 - b. Target temperature difference (with respect to background) = 4 degrees C.
3. Up to 65 percent of Field of View (FOV)
4. Maintain lock throughout the maneuvering envelope

5. Tracking rate of 75 degrees/second (maximum)
6. Tracking accuracy of 200 microradians
7. Detect the front end of a tank at a slant range of 8 nautical miles with 2.5 degrees C delta temperature
8. Track the detected target at ranges of 4-10 kilometers.

Area Track Function

AREA TRACK was the only track mode available during this study but it was used with some success. The area tracker/target correlator was designed to provide a fixed scene display and establish a stable scene for target designation by providing a FLIR lock on whatever was located at the center FOV. The area tracker used nine areas-of-interest (AOI), shown in appendix B, figure 19, to the FLIR picture. The target correlator AOI was located at the center FOV. The nine AOIs had dimensions of 63 pixels by 28 field lines. Within each AOI was an area-of-interest reference area (AOIRA). Each AOIRA was designed to store bi-level video and had dimensions of 42 pixels by 16 field lines. Each AOIRA was designed to scan within the AOI. The tracker/correlator was designed to compare the video within the AOIRA with its corresponding AOI stored bi-level video to perform a pixel by pixel scene correlation. This comparison allowed the tracker to maintain cursor position during scene changes as the aircraft approached the target. The major limitation to the AREA TRACK mode was its inability to maintain target track during momentary target obscurations caused by clouds or aircraft masking. Once the FLIR field of view became obstructed the target track was lost and had to be reacquired.

CENTER SECTION

The center section shown in appendix B, figure 20, housed the pod's power supply, Central Electronics Unit (CEU), Laser Electronics Controller (LEC) and the pod control computer. The pod control computer was designed as the pod's bus controller for the internal pod data bus. It used a MIL-STD-1750A architecture and was designed to provide the interface to the aircraft and pod subsystems. The power supply was designed to provide the pod with dc power and the LEC controlled laser operations.

AFT SECTION

The aft section shown in appendix B, figure 21, housed the Environmental Control Unit (ECU). The ECU was designed to provide overall targeting pod cooling, laser cooling and FLIR detector cooling. The environmental control system consisted of the ECU, the nose section blower and heaters, and various coldplates throughout the system. The ECU's designed cooling capacity was 2.6 kW based on operation at 0.85 True Mach Number (TMN) at sea level on a standard day.

POD-TO-AIRCRAFT BORESIGHTING

GENERAL

The purpose of boresighting was to ensure the FLIR optics could be pointed, to a high degree of accuracy, at a point coincident with other aircraft sensors and systems. This was to ensure that when transitioning from other sensors/systems to the FLIR, that the target was located within the FLIR field of view. Based on standard boresighting

procedures, the designed LANTIRN boresight accuracies were 1 milliradians in pitch and yaw and 2 milliradians in roll. This accuracy ensures that targets are within the FLIR FOV during the target acquisition phase and also provides accurate laser pointing during target designation and weapon guidance. Pod placement in relation to the aircraft datum line, mounting hardware and inflight pod motion are factors which can affect the accuracy of pod boresighting and were evaluated during the course of this study. Most aircraft which have integrated a FLIR targeting system, firmly mount the pod to the fuselage of the aircraft, relatively close to the datum line. By contrast, the mounting methods used during the F-14 during this study used a number of hardware components and locations. The affects of these deviations are discussed later.

Mechanical (Hardware) Boresighting

Mechanical boresighting was the primary method of pod-to-aircraft boresighting. This method required the determination of the orientation of the pylon hardpoints, to which the pod was attached, relative to the aircraft datum line. By attaching an appropriate boresight fixture, the pitch, roll and yaw orientation of the aircraft pylon attachment points from the 0-0-0 position can be measured. These coefficients can then be entered into the aircraft mission computer to provide mechanical boresight misalignment corrections. This boresight method was designed to be sufficient to maintain pod boresight accuracy and required no further boresighting procedures. Hardware boresighting required the FLIR pod be rigidly mounted to the aircraft as any inflight pod motion would degrade line-of-sight pointing accuracy. The LANTIRN TFLIR was designed such that boresight accuracy required recalibration every 50 flight hours.

Electrical (Software) Boresighting

Electrical boresight was the secondary method of pod boresighting. Electrical boresighting could be accomplished by selecting a target with the FLIR and aligning a visual cue such as a head up display (HUD) designator to the FLIR designator. Based on standard boresighting procedures, the designed software boresight accuracy to other aircraft sensors was 3.0 milliradians. This method was designed for use with targets of opportunity beyond 500 feet away and corrects alignment in the pitch and yaw axes only. No software boresighting corrections were available for the roll axis.

SCOPE OF TEST

GENERAL

Study of the LANTIRN TFLIR pod's structural compatibility and integration was conducted between 5 Oct to 8 Nov 93. The pod was provided by Martin Marietta Corporation, Orlando, Florida and was evaluated as installed on an F-14D(minus) aircraft, bureau number 161623, provided by Strike Aircraft Test Directorate (SATD). The primary purpose of the test program was to evaluate the pod for structural compatibility, airworthiness and physical fit. This scope of this study did not include actual pod structural analysis since this testing was done previously during initial pod development. What this study attempted to accomplish was to measure the vibration and acoustic loads, record these loads and then compare them to loads previously measured on the F-15E. It was reasonable to assume that loads measured on the F-14 would be comparable to loads on the F-15E based on the similarities in aircraft size and operating envelope. If the loads were comparable then the pod would be considered structurally compatible. The second purpose was to conduct a physical fit evaluation which considered four major configuration options to further determine pod compatibility. These options are summarized as follows:

1. LANTIRN Pod Station. The aircraft store station at which LANTIRN is installed. For this study, two options were considered: under the fuselage, station 6 and under the wing, station 8. Since the wing mount was less rigid, it was predicted that the loads here would be somewhat greater than those under the fuselage.

2. LANTIRN Mount Option. The LANTIRN TFLIR was mounted using two possible interface methods. In the first method, the LANTIRN pod interfaced with the Navy ADU-703 or HARM adapters via the MMTI pylon. This configuration is herein referred to as the ADU-703/MMTI interface. Alternatively, the TFLIR was attached to a standard BRU-32 bomb rack via MMTI bomb rack pylon. The BRU-32 bomb rack was then mated to the ADU-703 or HARM adapters. This configuration is herein referred to as the BRU-32/MMTI pylon.

3. F-14 Chin Pod. There were two options for the F-14 flight test; a dual chin pod (DCP) or a single chin pod (SCP). The study will shed light on the effects of these different chin pod configurations on the vibrations experienced by the pod. Since the wing pylon location is outside the flow field affected by the chin pod, the study focused on fuselage mount configurations to further compare the different mounting options.

4. Adjacent Store. With LANTIRN mounted on station 6 (under fuselage) there will most likely be a mission requirement to load a GBU weapon on the adjacent station 3. Since the GBU would be in close proximity to the LANTIRN pod, it could potentially alter the aerodynamic flow around the pod and also affect the pod field of regard. Unfortunately, flight clearance prevented flights with an adjacent GBU weapon, however ground tests were conducted with a GBU for field of regard determination. Clearance between the GBU and the LANTIRN pod were also measured to ensure fit compatibility.

The pod was evaluated 45.0 pod operating hours which included eight flights totaling 10.9 hours. Sub-sonic flight tests were conducted in the Patuxent River Restricted areas while supersonic flight tests were conducted in the off-shore supersonic test track.

All flights were conducted in day visual meteorological conditions (VMC). Weather and humidity conditions for each flight are shown in Table IV.

Table IV
WEATHER CONDITIONS DURING LANTIRN/F-14
COMPATIBILITY FLIGHTS

FLIGHT -DATE (1993)	ABS. TEMP (F)	REL HUM %	ABS HUM %	WIND (DIR/ KTS)	VIS (NM)	CEILING
1-10/6	60	45	7	020/14	5	30/200SCT
2-10/7	76	68	14	060/6	7	25SCT 200OVC
3-10/8	68	87	15	110/4	7	20SCT 100/250BKN
4-10/28	59	67	8	030/10	6H	E80BKN/120 BKN
5-11/1	47	51	4	310/16 G25	7	15SCT 30/120BKN
6-11/2	53	41	4	030/8	7	250 BKN
7-11/4	57	72	8	160/11	7	E250 BKN
8-11/8	43	76	5	250/4	7	250 OVC

All tests were conducted in SD220 with the test loadings shown in appendix C, Table I. Testing was conducted in the cruise and combat configurations which are shown in table V.

Table V
LANTIRN/F-14 TEST LOADINGS

	LANDING GEAR	FLAPS	POWER SETTING
CRUISE	UP	UP	AR ¹
COMBAT	UP	MANEUVER	AR ¹

Note 1: As required to maintain test parameters.

Aircraft gross weight varied from 47,500 to 65,200 lbs and the CG was maintained within aircraft design limits of 6.3 and 17.0% mean aerodynamic chord (MAC). The flight test envelope is shown in table VI. All test points where data were recorded are shown in appendix B, figure 22

Table VI
LANTIRN/F-14 FLIGHT ENVELOPE

PARAMETER	VALUE
Maximum Indicated Mach Number	1.33
Maximum Airspeed	600 KIAS
Altitude	Sfc to 40,000 ft MSL
Aircraft g Loading	0.0 to 4.0 g

All tests were conducted in accordance with the F-14A and F-14D NATOPS, reference 1, and 2. Test procedures were conducted as approved in the LANTIRN TFLIR/F-14D COMPATIBILITY test plan, reference 4 and the SATD standard operating procedures (SOP), reference 5. Since the program was a proof of concept and

preliminary compatibility evaluation, there were no specification compliance issues, however, vibration and acoustic data were compared with existing F-15E data. It was postulated that F-14D vibration loads were less severe than F-15E loads therefore all experienced loads which were less than or equal to the F-15E data were considered compatible. No ordnance was carried or released during flight testing.

LIMITATIONS

Testing was limited by the following:

a. Since the LANTIRN pod was not integrated through the aircraft's 1553 data bus, the pod's video and control panels were "hardwired" to the cockpit. This was a major limitation to the level of integration that was possible but did afford an opportunity to study a reduced capability system and its effects on overall mission utility. The level of integration prevented aircrew control of the following functions normally available in a TFLIR system:

- The FLIR image polarity was fixed, "white hot".

- There was no video gain control to allow the aircrew to adjust the display. The gain was preset and remained fixed throughout each flight. Engineers attempted to predict the best gain setting prior to each flight.

- The FLIR display, shown in appendix B, figure 23, had a variety of symbology to assist the aircrew in monitoring FLIR status, pointing angle and warn of any failures. The symbology was preset and fixed with white lettering and symbology.

b. Control of the pod was accomplished through a pre-fabricated control panel.

c. Structural compatibility was evaluated during up and away flight. The pod was not evaluated in the aircraft carrier environment which would have included catapult launches and arrested landings.

d. The pod was designated a "dry" pod which prevented flights into visible moisture.

e. No flights were conducted with ordnance on-board. This aspect prevented analysis of the vibration changes which may be induced by stores adjacent to the LANTIRN pod.

f. All flights were conducted during daylight hours for primarily safety consideration. All flights required flight at high speeds, low altitudes and high load factors, requiring a defined horizon.

g. An electro-optic test target (EOTT) and focal collimator were not available. FLIR resolution and minimum differential temperature evaluations were qualitative. Jitter loss determination and spatial frequency cut-off testing were not conducted.

This study was expected to develop preliminary conclusions concerning the pod's structural compatibility and the mission capability of the limited avionics integration. The study was also expected to draw initial conclusions as to the suitability of several mounting configurations and locations in addition to evaluating the overall effects of aircraft capability with the pod.

METHOD OF TEST

PROCEDURES

GENERAL

All tests were conducted in accordance with the LANTIRN/F-14D compatibility Test Plan, reference 4, as authorized by the Strike Aircraft Test Directorate Standard Operating Procedure (SOP), reference 5. Pod system tests were performed in accordance with the USNTPS systems test manual, reference 6. The inflight evaluation was conducted by both the pilot and RIO. The aircraft and pod were instrumented to record aircraft environment data and pod vibro-acoustic data throughout the flight envelope. Data were recorded on all flights; however a malfunction of the aircraft instrumentation recorder resulted in no data collection during the entire first flight. Data for flights 2 through 8 were considered valid. This determination was made by recording ambient pod conditions prior to each flight and analyzing the load values.

GROUND TESTS

Pod Fit Checks

Before flight test it was necessary to determine whether the pod would physically fit on the test stations using the test mounting equipment. For the fit to be considered satisfactory, the pod must be mounted and meet the specifications established by MIL-STD-1763A, reference 7. The specification for mounting external stores states that all

clearances between the store and all fixed and moveable aircraft components must be at least 1". In addition, the store must have a minimum of 6" of ground clearance. Pod clearances were measured on both stations 6 and 8 using both mounting methods. In addition, with the pod on station 6, using the ADU-703/MMTI adapter, clearances were measured with a GBU-10 on station 3. Measurements were made using a tape measure and where possible, photographs were taken to assist in accurately determining clearances.

Field of View

The LANTIRN instantaneous field of view was evaluated in both narrow and wide field of view during ground testing as well as in flight. The evaluation was conducted by observing the FLIR image and noting objects near the limits of the field of view. The distance to the objects was measured as well as the distance between, from which the actual fields of view were calculated. The mission utility of the field of view is determined by how easy or difficult target acquisition is given the errors in FLIR pointing. That is, is the field of view sufficiently large such that the target is within the FLIR image or is an excessive amount of manual slewing required to locate it. It is difficult if not impossible to conduct field of view evaluations during ground test since there is no way to simulate the target acquisition process. The demonstrated fields of view were calculated to be 2.0 degrees and 5.95 degrees in narrow and wide FOV, respectively, which is very close to the system specification published by the manufacturer.

Field of Regard

GBU delivery tactics may involve either high altitude or low altitude delivery profiles. The method of delivery determines the types of maneuvers required and further dictates the FLIR's minimum field of regard so as not to limit these maneuvers. In cases where the field of regard is obscured it must be quantified during ground evaluation to help predict areas of obscuration and to help aircrew to avoid FLIR obscuration in flight. The LANTIRN field of regard was evaluated to determine areas where the pod line of sight would be obstructed by aircraft components or other stores. The pod was linked via RS170 coaxial cable to an off-board video monitor and control panel which provided a joystick for manual slewing. During this study, the FLIR line-of-sight was slewed along the aircraft body lines and stores. The FLIR line-of-sight azimuth and elevation were displayed on the video monitor and recorded at reference points along the aircraft. These points were plotted on a 360 degree total vision plot to graphically present the areas of line of sight obstruction. The total vision plot proved very useful for predicting aircraft roll limits and pointing angles where tracking would be lost during flight test.

FLIGHT TEST

As stated earlier, the primary purpose for the flight portion of this study was for the collection of vibration and acoustic load data experienced by the pod at specific airspeed, Mach number and altitude conditions. The test points were selected by Martin Marietta structural engineers to ensure that a direct comparison of data would be possible. The points were selected at the extremes of the F-14 operating envelope and are shown in appendix B, figure 22. Several restrictions were imposed by flight

clearance authorization, particularly in the maximum load factor and Mach number with the dual chin pod installed and are pointed out in the flight clearances. This did not reduce the validity of the study as data were collected throughout the majority of the F-14 flight envelope. Sufficient time between data points allowed the flight crew to operate the FLIR in attempts to acquire targets of opportunity and qualitatively evaluate the FLIR's imagery and functionality. The pod line of sight elevation angle was set to 0 degrees and the field of view was set to "wide" for all data points to ensure repeatability.

Data Collection During Aircraft Acceleration

Data were recorded while performing both subsonic and supersonic accelerations at various altitudes. To provide useful data, the aircraft altitude, Mach and load factor were maintained constant within the specified tolerances of ± 1000 feet, $\pm 0.1M$, and $\pm .01g$. Data were recorded throughout the acceleration and once the target Mach was reached, it was held for 30 seconds to collect a large enough sample to be considered representative. Data collection continued during deceleration through transonic speeds.

Data Collection During Wind Up Turns

Data were recorded while performing accelerated wind up turns (WUT). Wind up turns were performed using the same tolerances as above, by gradually increasing aircraft g loading until heavy buffet or 4.0 g was reached. The heavy buffet or 4.0 g was sustained as long as possible up to 30 seconds for consistent data recording.

Target Acquisition

One important question to be answered was whether a minimal installation would support target acquisition. The system was evaluated for utility and ease during simulated weapon delivery profiles in an attempt to study the usefulness of the control panel. Target acquisition required a tremendous amount of coordination between the pilot and RIO. The pilot maneuvered the aircraft until the desired target was within the FLIR field of view. The RIO then observed when the target image was centered under the cursor and commanded AREA TRACK. Video was recorded during the acquisition process and during subsequent target tracking.

Target Tracking

Since the LANTIRN pod did not support slaving to sensors or INS points, it was not expected to perform well during target tracking since the image was not inertially stabilized. But to investigate further how useful the integration was, LANTIRN target track capability was evaluated during simulated weapon delivery profiles. Target tracking was accomplished by commanding AREA TRACK with the desired target located within the FLIR field of view using the above described acquisition procedures. By marking prominent image reference points on the FLIR aircrew could qualitatively assess the system's tracking capability. The AREA TRACK function was a correlator which performed a scene-to-scene comparison and, coupled with the pod's internal gyro stabilization was designed maintain the target in the field of view.

Target Identification

A FLIR's performance is measured primarily by its angular resolution since it determines the system's usefulness for target identification. Although this study did not focus on quantifying the system's resolution, the evaluator did perform qualitative tests to determine the utility of the system for target identification. Measuring FLIR system angular resolution can be performed under static conditions during ground testing and this is useful primarily for determining specification compliance. But angular resolution can be severely degraded by line-of-sight jitter during flight. This study was not to quantify jitter losses but to identify potential jitter sources resulting from the different integration methods. Studying the integration and measuring vibration would help predict the dynamic performance of the LANTIRN. The LANTIRN's utility in aiding target identification was evaluated during simulated weapon delivery profiles. The aircrew evaluated the FLIR video for clarity and utility while maneuvering the aircraft and attempting to recognize, categorize (i.e. tank, building, truck or car) and identify (i.e. hangar, hospital, M-1 or T-72 tank) targets at the greatest range. By performing maneuvers at various speeds and load factors, the aircrew could determine if or when imagery degradation could be attributed to jitter losses. The aircrew also made qualitative comments concerning the clarity and stability of the image for each mounting configuration to help identify satisfactory mounting configurations.

INSTRUMENTATION

POD INSTRUMENTATION

To gather vibration and acoustic load data the LANTIRN pod was instrumented by installing a number of receivers on the pod. Two angular rotation accelerometers, eleven linear accelerometers, three acoustic microphones and two Rate Integrating Gyroscope (RIG) output test points, were placed as shown in appendix B, figure 24, to gather the vibro-acoustic environmental data. A detailed breakout of instrumented data is provided in appendix C, table II. These data points were routed to the aircraft instrumentation through the targeting pod/aircraft interface connector at the pylon. The placement of each data receiver corresponded to the placement during similar collection efforts previously conducted on the F-15E since these were the data to be used for comparison.

AIRCRAFT INSTRUMENTATION

The F-14 was instrumented to simultaneously record the following aircraft parameters: mach number, altitude, true airspeed, angle of attack (AOA), aircraft normal acceleration, aircraft pitch rate, aircraft yaw rate, aircraft roll rate, pilot audio and time. These parameters were recorded on the aircraft's on-board MARS 2000 instrumentation recorder. Since the aircraft was not tracked by ground tracking equipment, these aircraft parameters were used as truth data.

INSTRUMENTATION RECORDER

The aircraft instrumentation inputs were recorded on ten tracks of the aircraft's 14 track recorder. The ten inputs were recorded wide band while the remaining 18 input channels were multiplexed on the remaining four tracks.

FLIR VIDEO RECORDER

RS170 compatible video was recorded internally in the pod's own 8mm TEAC recorder and also on the aircraft's VHS format video recorder. The aircraft recorder also included time tag data and cockpit audio. After each flight, both video cassettes were downloaded and played back in the post-flight debriefing for a "quick look" evaluation of the flight. This helped aircrew and engineers identify problems which may have occurred with sufficient time to make changes to the next flight, if required.

RESULTS AND DISCUSSION

VIBRO-ACOUSTIC DATA COMPARISON WITH F-15E DATA

GENERAL

The data collected during F-14 flight test were reduced by Martin Marietta and plotted in formats which allowed direct comparison between the F-14 environment and LANTIRN operational specifications, derived from historical F-15 data. Pod structural compatibility with the F-14 flight environment was evaluated by plotting the F-14 vibration amplitudes versus the operational specifications spelled out for the F-15E. Data from each flight were plotted to depict vertical and lateral vibration measured in the nose, center and aft pod sections. In addition, acoustic power sound pressure levels recorded by the left and right acoustic microphones were plotted versus the F-15/F-16 acoustic specification. Finally, composite plots of all flight data were generated to compare several integration options: wing mounting vs. fuselage mounting, dual chin pod vs. single chin pod, and mounting using the BRU-32/MMTI bomb rack pylon vs. the ADU-703/MMTI pylon.

STRUCTURAL COMPATIBILITY

From each of flights 2 through 8, a set of nine plots were generated to depict the following characteristics:

Nose and aft section vertical vibrations

Nose and aft section lateral vibrations

Gimbal and Center section lateral vibrations

Nose section port and starboard sound pressure levels

Nose acoustic cavity sound pressure levels

Appendix C, table III provides a generalized matrix depicting how F-14 data compared with the F-15E operational specification as derived from these plots. The data did reveal an interesting trend at frequencies below 70 Hz. The greatest vibration loads measured in this low frequency region were correlated to times in flight at which the aircraft was operating in moderate to severe airframe buffet. The data also presented a series of discrete harmonic vibrations at 100, 200 and 300 Hz. These discrete harmonics were attributed to the reciprocating Environmental Control Unit (ECU) compressor and were not considered environmentally induced loads. These harmonics remained fairly consistent in magnitude throughout each flight and did not seem to vary with mounting or pod location.

FUSELAGE VS WING MOUNTED POD

Analyzing data from flight two and flights four and five provide a good comparison of wing vs. fuselage vibration loads since these flights were nearly identical in their flight profile. For both flights the aircraft had the single chin pod installed and used the ADU-703/MMTI adapter for pod mounting. The plot of vertical nose section vibration for both the fuselage and wing station, depicted in appendix D, figures 1 and 2 show an increase in the vibration loads with the pod mounted on the wing station. The increase

occurs again, during airframe buffet, particularly below 100 Hz. During several recording events, the vibration loads exceeded the F-15E specification in this region. While this was not be considered severe enough to cause structural failure, it did raise concern as to the pod's compatibility in the wing mounted configuration.

ADU-703 VS BRU-32 PYLON

The measured loads in the ADU-703 and BRU-32 were comparable throughout the pod and the F-14 envelope. Appendix D, figures 3 and 4 show vibration load measurements recorded during flights 2 and 3 for the nose section. These plots showed the vibrations were comparable for both mounting methods. The major difference between the two mounting options, however, was the measured rigid body translation which was determined during ground test. During pre-flight, the BRU-32 permitted the pod to sway and measurements showed as much as 0.5 inches of side-to-side lateral play. Upon post-flight, the BRU-32 self-tightening sway brace feet had loosened and the measured lateral play exceeded 1.0 inch. The excessive play would induce substantial Line-of-sight pointing errors and increase boresighting problems. On all flights with the pod mounted on the BRU-32, the aircrew reported noticeable and sometimes severe vibration and degradation of the FLIR video image during simulated GBU delivery profiles. The boresight errors coupled with the degradation in FLIR resolution will increase the aircrew's workload during target acquisition. In addition, the degradation in FLIR imagery would decrease detection, acquisition and identification ranges. The effects of BRU-32 side-to-side freeplay was not quantified but it is predicted that the LOS pointing errors induced by this motion will be unsatisfactory for target acquisition. The ADU-703 configuration did exhibit a slight

amount of lateral freeplay but it did not appear to affect the FLIR imagery. To correct this, Martin Marietta designed a potential solution to eliminate all freeplay in the ADU-703 interface. The interface tightening device shown in appendix B, figure 25 was designed to replace existing mounting pins such that once mounted, it could be locked by engaging a locking pawl, to remove any ADU-703 freeplay. Overall, the pod is considered structurally compatible in both mounting configurations but the boresighting and resolution issues decrease the utility of the pod on the wing station.

SINGLE CHIN POD VS DUAL CHIN POD

The plots shown in appendix D, figures 5 and 6 show that the vibration and acoustic loads for the dual chin pod were not substantially different from those measured with the single chin pod installed. The vibration loads measured in the aft section with the dual chin pod were slightly higher for the dual chin pod, at frequencies above 500 Hz. Overall, the dual chin pod configuration experienced marginally higher load levels than the single chin pod configuration but the vibro-acoustic loads for both the fuselage and wing mounted pod configurations were within the F-15/F-16 operational specifications. The pod was therefore considered structurally compatible with either the dual or single chin pod installed.

FIELD OF REGARD

FUSELAGE MOUNTED POD

The LANTIRN pod was first quantified during ground tests, then evaluated in flight while executing simulated GBU delivery profiles. First, the pod was mounted on station 6 with no stores on station 3. The aircraft was evaluated with and without drop tanks on stations 2 and 7. A baseline total vision plot for the pod on station 6 and a clean aircraft (no tanks, no stores) is shown in appendix D, figure 7. A total vision plot for the pod on station 6 with tanks on station 2 and 7, is shown in appendix D, figure 8. With the pod on station 6, with tanks, the Pod LOS was obstructed at elevation angles above 30 degrees. In flight, whenever the aircraft was rolled 35 degrees in the direction of the target during simulated GBU delivery maneuvers, LANTIRN FLIR pod LOS was obstructed by the aircraft and simulated laser illumination was lost. To compensate the pilot had to maintain wings level or limit turns to one direction to prevent line of sight obstruction due to the restrictive field of regard. By repeatedly attacking targets and flying the exact same profile, F-14 aircrew will establish a predictable pattern which hostile forces can use to anticipate maneuvers. This is a distinct advantage to hostile forces allowing them to pre-stage weapons and increase their effectiveness against the F-14. Aircrew will have a choice either to remain predictable and risk being shot down or maneuver and risk masking the FLIR resulting in loss of laser designation and bombs missing the target. For these reasons, the restrictive field of regard with the pod on station 6 was considered a major limitation which must be corrected prior to introducing the pod to the fleet.

FUSELAGE MOUNTED POD WITH ADJACENT GBU-10

During ground test the pod was also mounted on station 6 using the ADU-703/MMTI mount with a GBU-10 on station 3 and the aircraft was evaluated with and without drop tanks on stations 2 and 7. A total vision plot for the pod on station 6 with the GBU on station 3 and tanks on station 2 and 7, is shown in appendix D, figure 9. Station 6 pod LOS was obstructed aft of 25 degrees left and above 55 degrees down from the horizon with the GBU-10 on station 3. The field of regard with the pod on station 6 was restricted and even more so with the GBU on station 3. The closeness and size of the GBU-10 to the TFLIR optics essentially masked the left side of the FOR. The restrictions with the pod on station 6 were compounded by the GBU so to compensate for the restrictive FOR with an adjacent GBU-10, the aircrew had to further limit targeting to the right side of the aircraft and maintain turns in the direction of the target to prevent LOS obscuration.

WING MOUNTED POD

The LANTIRN pod was evaluated for field of regard during ground test and simulated GBU delivery profiles with the pod was mounted on station 8 and drop tanks on stations 2 and 7. A total vision plot for the pod on station 8 and tanks on station 2 and 7, is shown in appendix D, figure 10. LANTIRN pod LOS was obstructed aft of 75 degrees left of the nose and above 30 degrees down from the horizon. Pod LOS was obstructed any time targeting was attempted to the left of the nose and aircraft maneuvers exceeded 20 degrees left angle of bank. FOR was unrestricted to the right. LANTIRN TFLIR LOS will be obstructed by the aircraft and stores due to the restrictive field of regard on station 8 resulting in bombs missing the target. Once

again, the evaluators had to maneuver to keep targets on the right side of the aircraft (With the pod on the left wing, targets would have to be kept on the left side) to prevent line-of-sight masking restricting maneuverability as described above. The restrictive field of regard on station 8 is a deficiency which must be corrected prior to fleet introduction.

TFLIR COOLDOWN TIME

LANTIRN FLIR cooldown was evaluated for time to completion during ground evaluation prior to each flight and ground test. On-board the aircraft carrier, F-14 routinely maintain an alert-5 status in which the aircraft is expected to launch, fully mission capable within 5 minutes of notification. Common module cryogenically cooled FLIR systems, such as the LANTIRN, require a period of time to lower the temperature of the IR detector to its optimum operating temperature. The average time for completion of this cooldown was 9.8 minutes. This excessive cool-down time will result in delaying alert launch aircraft until pod status can be determined. For normal launches the time to cooldown will not be a factor since they typically take from 10-15 minutes. F-14 aircrew will delay launch due to the excessive targeting FLIR cooldown resulting in delays in conducting the alert-5 launches. The excessive cooldown time of the LANTIRN FLIR is a deficiency which must be corrected as soon as possible.

TFLIR SYMBOLOGY

Though the integration was limited, it was worthwhile to note the usefulness of the TFLIR symbology. LANTIRN TFLIR symbology was evaluated for clarity and

readability during simulated GBU delivery profiles from 500 ft AGL to 12000 ft MSL at speeds from 250 to 600 KIAS with the pod commanded to AREA TRACK. FLIR image polarity was fixed in "white hot" and video gain was fixed. Whenever the symbology was written over white video imagery, which occurred roughly 50% of the time, the symbols were not readable: These symbols included pod pointing angle and elevation, and track mode. The unreadable TFLIR pointing angle and elevation prevented the evaluator from executing proper delivery maneuvers resulting in extra time maneuvering the aircraft prior to weapons release. The unreadable TFLIR symbology against similar FLIR video images will delay aircrew from executing GBU release resulting in increased exposure to enemy air defenses. It is understood that in a complete integration, there will be two symbol color selections to aid the operator. The problems with the single symbol color are pointed out so as not to overlook this aspect in future integrations.

AREA TRACK

Use of the AREA TRACK function was essential for conducting much of the analysis of the pod's utility. The LANTIRN pod was evaluated for function and utility during simulated GBU release maneuvers from 500 ft AGL to 12000 ft MSL at speeds from 250 to 600 KIAS with the pod commanded to AREA TRACK. Aircraft maneuvers included 360 degree rolls, 4.0g sustained turns and turn rates up to 20 deg/sec. The AREA TRACK mode allowed the evaluator to maintain situation awareness on a bridge pylon during all maneuvers which were not masked by the aircraft. The AREA TRACK maintained track accuracy within an estimated 100 feet of the original track from 20 NM until overflight of the target. While this was not adequate for GBU

delivery, it was sufficient to hold the target within the FOV and if a manual slew capability were available the evaluator would have been able to update the cursor position with minimal workload. One problem with AREA TRACK was observed whenever a thin cloud momentarily blocked the line-of-sight. When this occurred, the pod shifted automatically to a rate track mode, always resulting in the pod being automatically slewed off the target. The accuracy of the AREA TRACK mode will improve aircrew Situational Awareness (SA) in a cloudless environment. If integration supported slaving the pod to another sensor or waypoint, the pod could easily be commanded back to the original target.

POD INITIATED BUILT IN TEST (IBIT)

The FLIR system must have the capability to self-test and reliably identify system problems with minimal false failure indications. The LANTIRN TFLIR IBIT was evaluated for time to completion and reliability prior to all flights and ground tests. The average time to complete IBIT was 1.3 minutes. The IBIT successfully identified all pod failures when they occurred. The IBIT also had a zero false alarm rate during this program which allowed the evaluator to launch with confidence that the TFLIR pod was fully operational. F-14 aircrew will launch with full system confidence due to the reliable and quick TFLIR IBIT. The reliability and quickness of the LANTIRN IBIT is an enhancing characteristic which will increase mission effectiveness.

POD RELIABILITY

LANTIRN TFLIR was evaluated for reliability during 45 total operating hours including ground and flight testing. The TFLIR experienced one critical pod failure during the test program resulting in an aborted flight. The failure was attributed to moisture intrusion into a sealed component of the optics housing. The intrusion was attributed to maintenance which was not conducted in accordance with published maintenance procedures. When published procedures were followed, the pod experienced zero critical or non-critical failures. The evaluator launched on all flights with full confidence in the system's performance based on the established reliability of the TFLIR. F-14 aircrew will launch with full confidence and the pod's reliability will increase effectiveness during the air-to-ground mission.

MISSION UTILITY

TARGET ACQUISITION

The LANTIRN TFLIR was evaluated for ease of acquisition during simulated attack profiles from 500 ft AGL to 12000 ft MSL at speeds from 250 to 600 KIAS. The pod was evaluated on both stations 6 and 8. FLIR LOS depression angle was set at either 0 or 2.5 degrees down. Target acquisition was accomplished by maneuvering the aircraft until the target appeared in the FLIR field of view. The evaluator had to depress the LOS button on the FLIR control panel and time the release of the button to coincide with the pilot's maneuver of the aircraft as he attempted to position the cursor over the target. It took an average of 3 attempts to track the correct target. The evaluator was never able to establish a track which was acceptable for precision ordnance release as a

result of the random unpredictable target acquisition procedures. Integration of a precision slew capability was beyond the scope of the test program but the difficulty of accomplishing target acquisition without it is worthy of discussion since the capability is essential to accomplish the precision attack mission. The random and unpredictable procedures required to accomplish target acquisition with the FLIR as integrated on the F-14 is a deficiency which must be corrected prior to future testing.

FLIR RESOLUTION

LANTIRN FLIR resolution was qualitatively evaluated during ground test and during simulated GBU weapon delivery at altitudes from 500 ft AGL to 12,000 feet MSL and at speeds from 250 to 600 KIAS. The system was evaluated in both narrow and wide field of view and the pod was mounted on the fuselage station using the ADU-703/MMTI adapter. During simulated weapon delivery maneuvers the FLIR was able to resolve the support pylons of a 500 foot bridge, which were positioned approximately 40 feet apart, at 7.5 NM. The sufficient resolution of the targeting FLIR provided sufficient time for the evaluator to position the cursor onto a specific bridge pylon during simulated weapon delivery. Since the pod could not be manually slewed, it was difficult to evaluate the FLIR's capability to identify vehicles, however, while tracking the bridge, the evaluator could distinguish between passenger cars and large trucks traveling across the bridge. The Vienna power plant was initially detected and recognized with sufficient definition to command an AREA TRACK at 38 NM. At 26 NM, several petroleum tanks were clearly discernible and could have been individually targeted. At 19.5 NM, the individual pylons of the nearby Vienna bridge were identifiable and again could have been individually targeted. With the pod

mounted on station 6 using the BRU-32, the distinction between trucks and cars was not obvious until inside 5 NM. This decrease in performance was attributed to the increased lateral motion on the BRU-32. Using the ADU-703 interface, the resolution of the LANTIRN FLIR is considered acceptable since it provided sufficient range to perform target detection and identification. The resolution of the LANTIRN using the BRU-32 is considered unsatisfactory due to the substantial decrease in target recognition ranges.

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

In efforts to help the Navy understand various aspects of TFLIR integration, this study focused on determining preliminary structural compatibility by comparing it with previously obtained F-15E and F-16 data. In their efforts to quickly integrate a pod on the F-14, the Navy has overlooked several technical issues which will affect pod boresighting, resolution and overall mission utility.

STRUCTURAL COMPATIBILITY

The LANTIRN TFLIR pod was considered structurally compatible with the F-14 flight envelope as integrated on either station. The loads measured on station 8 did exceed F-15 operational specifications but were probably not sufficient to warrant exclusion from integration consideration. The vibration and acoustic loads measured throughout the F-14 flight envelope were at most points less than or equal to the F-15/F-16 operational specification. Most cases where vibration loads exceed F-15/F-16 operational limits were attributed to the ECU. Why this increase in loads occurs with the pod on the F-14 was, however, an issue requiring further investigation. Since pod data were not collected during catapult launches and arrested landings, its carrier suitability was not determined. Based on load measurements for other stores which have undergone F-14 carrier suitability testing, the vibration loads may be substantially higher than predicted. Aircraft during carrier suitability testing experience sink rates up to 23 feet

per second on touch-down and when coupled with induced yaw, pitch and roll rates, and the force of an arrested landing, the loads on the LANTIRN pod may be higher than expected. Further testing for carrier suitability must be conducted before structural compatibility can be certified.

FIELD OF REGARD

The LANTIRN field of regard is unsatisfactory as integrated on both stations 6 and 8. The limits to FLIR FOR will force aircrew to limit ground attack tactics and target area maneuvering to deliver air-to-ground stores successfully. Aircrew will be forced to compensate to the FOR limitations by planning all target ingresses in one direction such that the pod LOS is always toward the unmasked side of the aircraft. This creates aircraft predictability during ingress and weapon release which allows hostile forces to develop simple anti-air tactics. In addition, to prevent LOS masking during weapon release and target lasing, the aircraft must maintain a flight profile which allows continuous target tracking. This means the aircrew must conduct shallow bank angle turns in the direction of the LOS. These maneuvers will increase aircraft exposure to surface-to-air defenses and further create aircraft predictability. This predictability and increased exposure will result in the loss of aircraft and aircrew and an alternate integration method must be investigated. One such alternate proposal was to embed the FLIR system into existing aircraft components. This proposal is shown in appendix B, figure 26. The embedded option proposed housing the LANTIRN weapon replaceable assemblies (WRA) within the existing AIM-54 fairings and mounting the FLIR optics in the adjacent fairing. Embedding the FLIR in the fairings would position the FLIR optics forward of the obstructions caused by the external fuel tanks and any stores

mounted on the fuselage stations. Positioning of the optics relative to the aircraft and stores is shown in appendix B, figure 27. By inspection, the FOR appears to be greatly improved but further quantitative testing would be required.

BORESIGHTING

HARDWARE BORESIGHTING

The accuracy of the LANTIRN pod boresighting was predicted to be unsatisfactory on both the BRU-32 and ADU-703 mounts due to the excessive freeplay and loose mounting methods. Based on discussions with Martin Marietta integration engineers, the BRU-32's excessive lateral side-to-side motion could induce excessive pointing errors on the order of 50 milliradians where 1 milliradian accuracy was required. An alternate mounting method must be investigated which will reduce LOS pointing errors. One such method, proposed by Martin Marietta, was a tightening adapter, shown in appendix B, figure 25. The MM tightening adapter was designed to fit in the ADU-703 mounting pin holes and remove the clearance between the weapon rail and the ADU-703 by engaging a rotating pawl. No such tightening adapter was considered possible which would make the BRU-32 mount satisfactory. The above mentioned embedded FLIR option was also considered a solution to reducing boresight errors and inflight LOS pointing errors because the fairings were hardmounted to the aircraft fuselage with no perceptible freeplay. Hard-mounting the pod to the airframe was the preferred integration method on the F-16 and F-15E which have demonstrated LOS pointing accuracy's of less than 1.0 milliradians. Further testing of the effects of catapult launches and arrested landings on pod boresighting must also be conducted.

MISSION UTILITY

The AREA TRACK function demonstrated excellent stability during all phases of flight. Even without a fully integrated slew capability it was possible to conclude it would greatly increase aircrew Situational Awareness (SA) and provide for easy target acquisition. Further testing is recommended with a fully integrated TFLIR pod to include all slewing, tracking and image optimizing capabilities. The pod must also be integrated through the mission computer to allow sensor to sensor target hand-offs and multi-sensor targeting capability. Further testing conducting actual ground attack profiles is recommended to quantify the effects of the field of regard on the ground attack mission. Further testing is recommended while conducting actual GBU weapon delivery to further quantify the effects of the restrictive field of regard and determine the impact of predicted boresight errors. Further testing of a fully integrated pod is recommended to evaluate system utility and quantify aircrew workload during low level ingress, high altitude delivery and GBU loft profiles.

FLIR RESOLUTION QUALITATIVE ASSESSMENT

The TFLIR resolution was qualitatively evaluated and considered a positive characteristic of the LANTIRN pod system. It was concluded that the FLIR pod's resolution when mounted on the ADU-703 will provide the aircrew with a superb capability to detect and identify targets at long range. While funding and time did not support it during this study, further testing is required to quantify the pod's resolution, spatial cut-off frequency, loss due to jitter and the minimum resolvable temperature differential. This testing will require use of a resolution bar target. It can be predicted that the BRU-32 mounting method will cause excessive jitter losses based on observed

degradation of the FLIR image during flight test. Integrating the pod on the wing may experience losses greater than that of the fuselage but this study did not support a firm conclusion.

AVIONICS INTEGRATION

The level of integration for this study would not support conduct of the air-to-ground mission. Aircrew workload during target acquisition was extremely high and the level of crew coordination required that the evaluator focus solely on the task of target acquisition, neglecting all other flight responsibilities. During an actual strike mission, the F-14 pilot and RIO would neglect other tasks such as air-to-air look-out and defensive maneuvering during target acquisition which may cause them to overlook an incoming SAM or air threat. Integration through the pod control panel was unsatisfactory. An important learning point from this study was a heightened awareness of the minimum capabilities necessary to accomplish the precision attack mission. The importance of functions such as manual slaving, slewing to other sensors or waypoints and real-time control of FLIR imagery became immediately apparent during this study as aircrew attempted to perform functions they were familiar with.

CONCLUSIONS

This quick-reaction study to integrate the LANTIRN Targeting Pod on the F-14 was successful in several respects in spite of the limitations to testing. First, the LANTIRN pod demonstrated physical compatibility with the F-14 without modification to the aircraft. The fabricated hardware proved to interface well with existing aircraft

hardware and no foreseeable modifications to the aircraft or targeting pod were required. While mounting the pod proved successful, determining structural compatibility provided some important lessons for consideration if the Navy goes ahead with full-scale LANTIRN procurement. The study successfully demonstrated the vibration loads experienced in the F-14 flight envelope should not be sufficient to damage the pod. The study also afforded aircrew an opportunity to take a qualitative look at different integration methods and their affect on pod performance. A key lesson learned was the importance of maintaining a field of regard as obstruction-free as possible. For this reason the Navy should investigate other integration options, such as the embedded proposal, to position the pod in another location. Perhaps a system could be developed which would fit in place of the single or dual chin pod. The study was important for increasing the F-14 community's understanding of the issues surrounding FLIR integration and that a bolt-on, plug-in, turn-on system will not provide the aircraft with the capability to do the mission as it is intended. A tremendous amount of testing is still required, but the study will be useful in directing the Navy away from risky integration methods and toward the methods with the highest probability of success.

APPENDICES

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ACRONYMS AND ABBREVIATIONS

A/A- Air-to-Air

AAA- Anti-Aircraft Artillery

AB- Afterburner

A/G- Air-to-Ground

AGL- Above Ground Level

AIM- Air Intercept Missile

AOA- Angle of Attack

AOI- Area Of Interest

BDA- Battle Damage Assessment. The ability to determine the level of damage inflicted upon a target

BIT- Built In Test

BKN- Broken cloud layer

CCG- Computer Control Guidance

CEU- Central Electronics Unit

CRT- Cathode Ray Tube

DCP- Dual Chin Pod designed to house the TCS and IRSTS on F-14D aircraft.

DP- Display Processor

ECU- Environmental Control Unit

EOTT- Electro-Optic Test Target

FAD- Fleet Air Defense

FLIR- Forward Looking Infra-Red

FOR- Field of regard

FOV- Field of View

G- Load factor

HARM- High Anti-Radiation Missile

HCU- Hand Control Unit

HOTAS- Hands on Throttle and Stick

HSI- Horizontal Situation Display

HUD- Heads Up Display

IBIT- Initiated Built In Test

IMN- Indicated Mach Number

INS- Inertial Navigation Set

IR- Infra-Red

IRSTS- Infra-Red Search and Track Set

KIAS- Knots Indicated Airspeed

LANTIRN- Low Altitude Navigation and Targeting Infra-Red Night

LBA- Limits of Basic Aircraft

LD- Laser designator

LEC- Laser Electronics Controller

LGB- Laser Guided Bomb

LOS- Line of Sight

MCS- Mission Computer Set

MFD- Multi-Function Display

MMTI- Martin Marietta Technologies Incorporated

MSL- Mean Sea Level

NATOPS- Naval Air Training Operations Procedures Standardization

NAWC AD- Naval Air Warfare Center, Aircraft Division

OVC- Overcast cloud cover

PGM- Precision Guided Munitions

SA- Situational Awareness

SATD- Strike Aircraft Test Directorate

SCP- Single Chin Pod designed to house the TCS on F-14A and B aircraft.

SCT- Scattered cloud layer

SOP- Standard Operating Procedures

TCS- Television Camera Set

TFLIR- Targeting Forward Looking Infra-Red

TID- Tactical Information Display

TMN- True Mach Number

USNTPS- United States Naval Test Pilot School

VMC- Visual Meteorological Conditions

WRA- Weapons Replaceable Unit

WUT- Wind Up Turn

PHOTOGRAPHS AND ILLUSTRATIONS

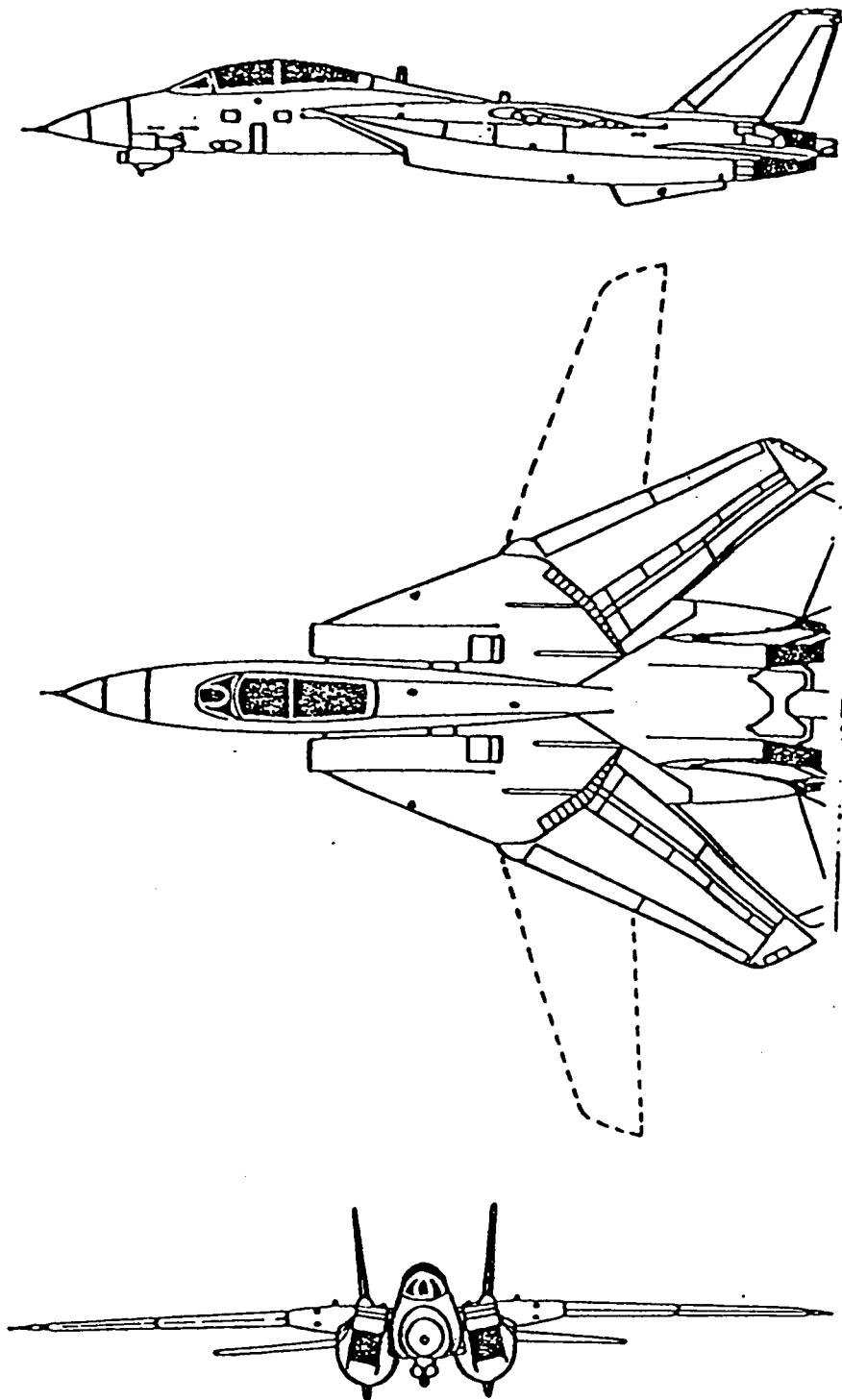
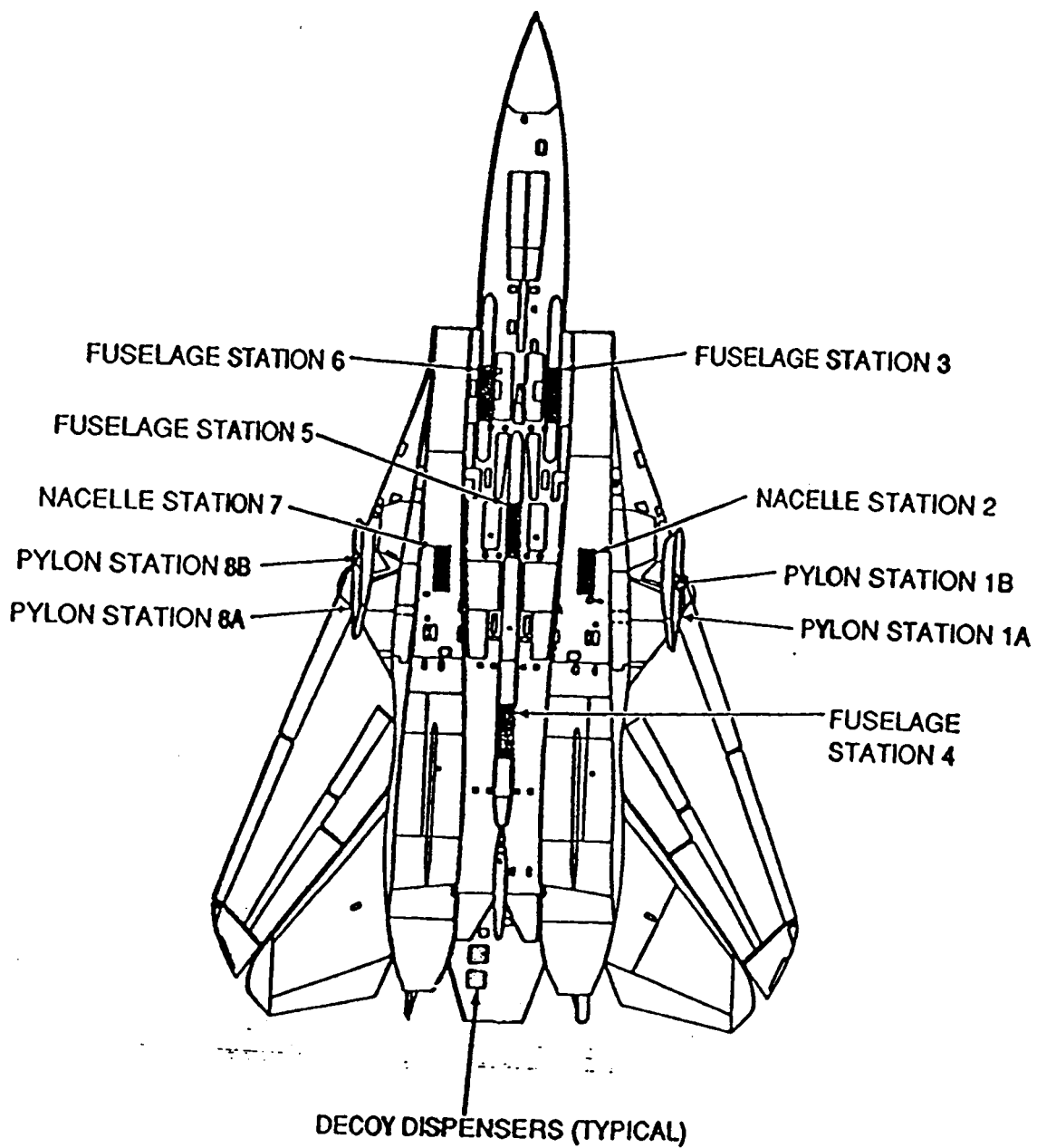


FIGURE 1
F-14 AIRCRAFT



DECOY DISPENSERS (TYPICAL)

VIEW LOOKING UP

FIGURE 2
F-14 WEAPON STATIONS

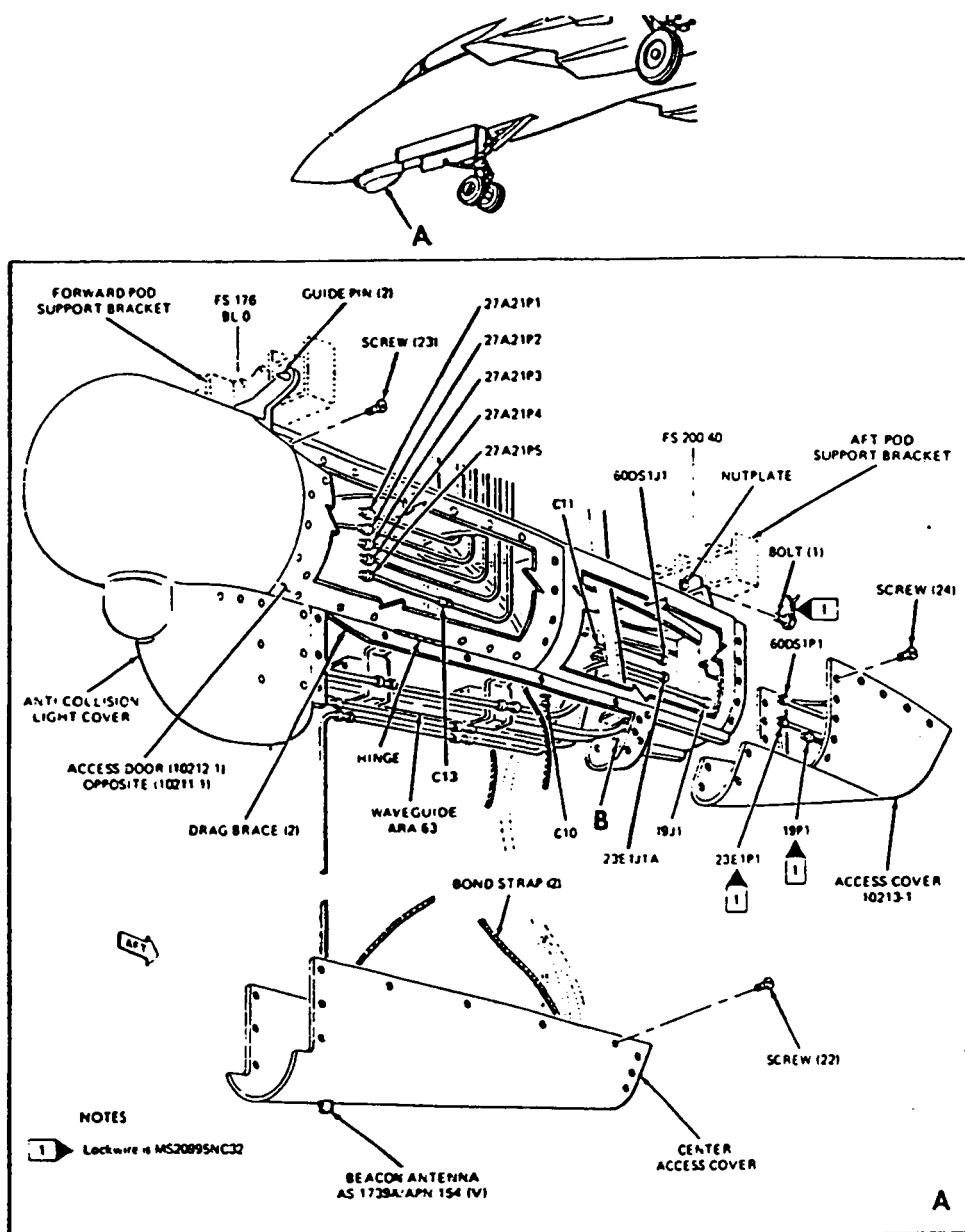


FIGURE 3
F-14 SINGLE CHIN POD

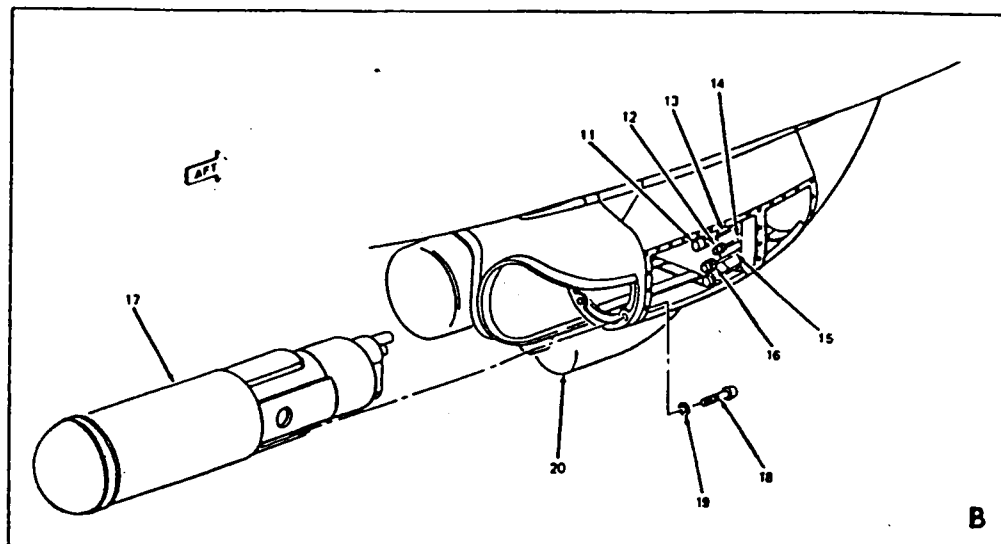
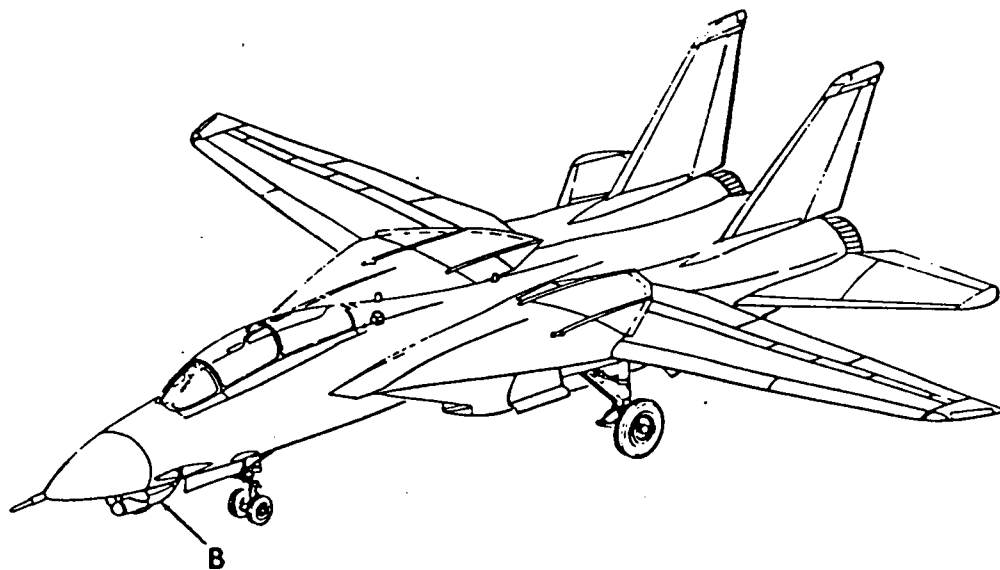


FIGURE 4
F-14 DUAL CHIN POD

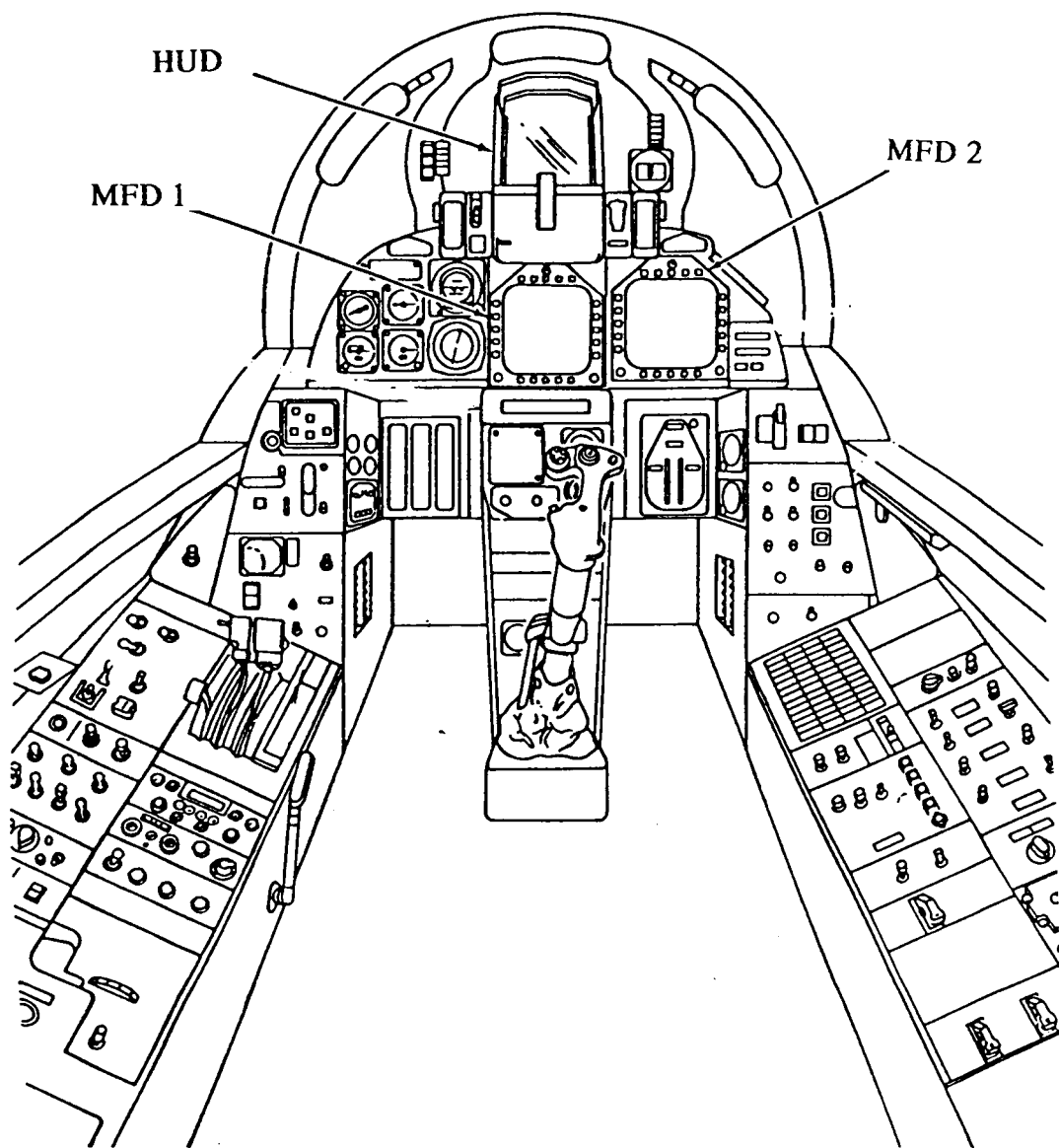


FIGURE 5
F-14 FRONT COCKPIT

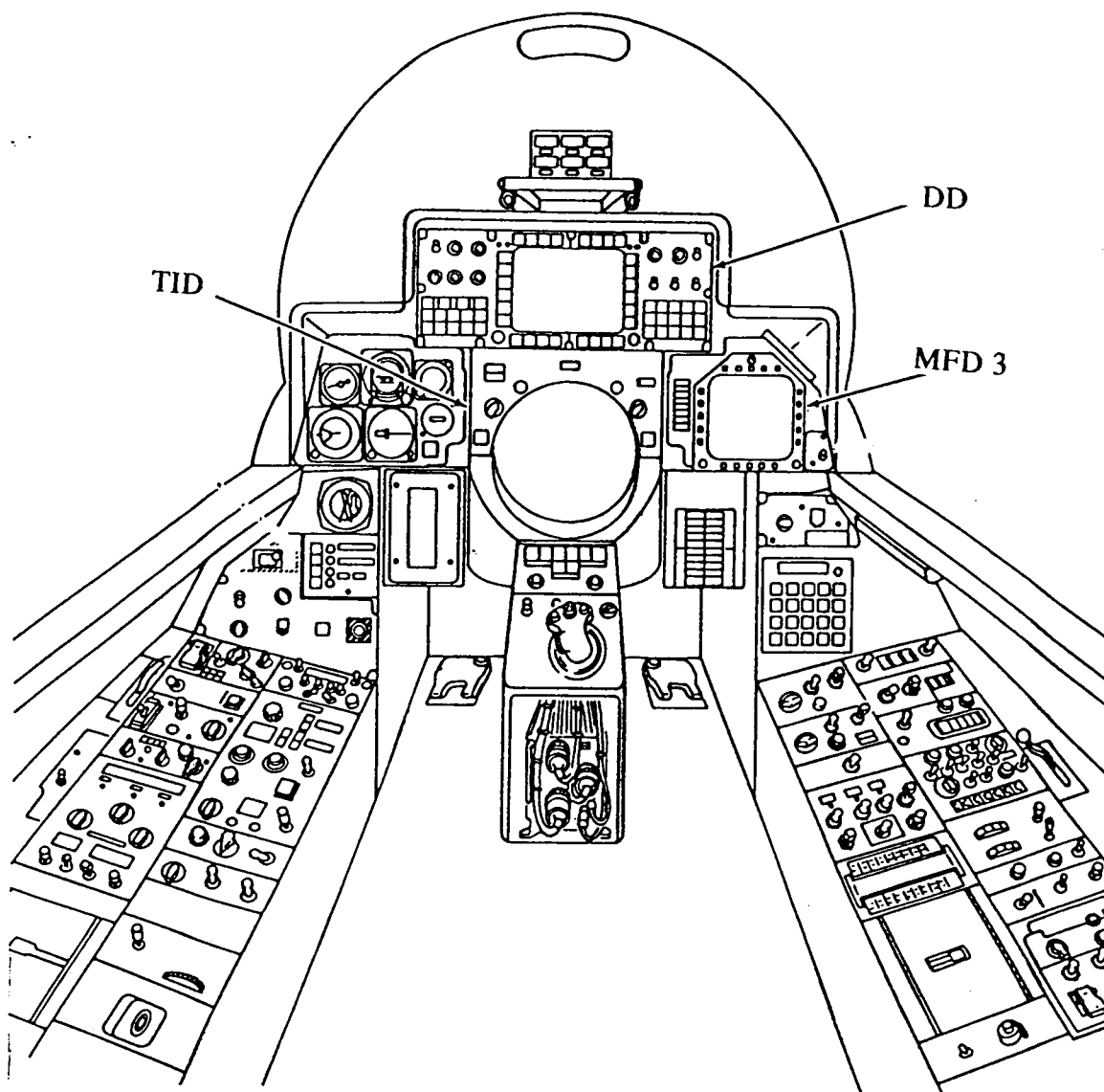


FIGURE 6
F-14 REAR COCKPIT

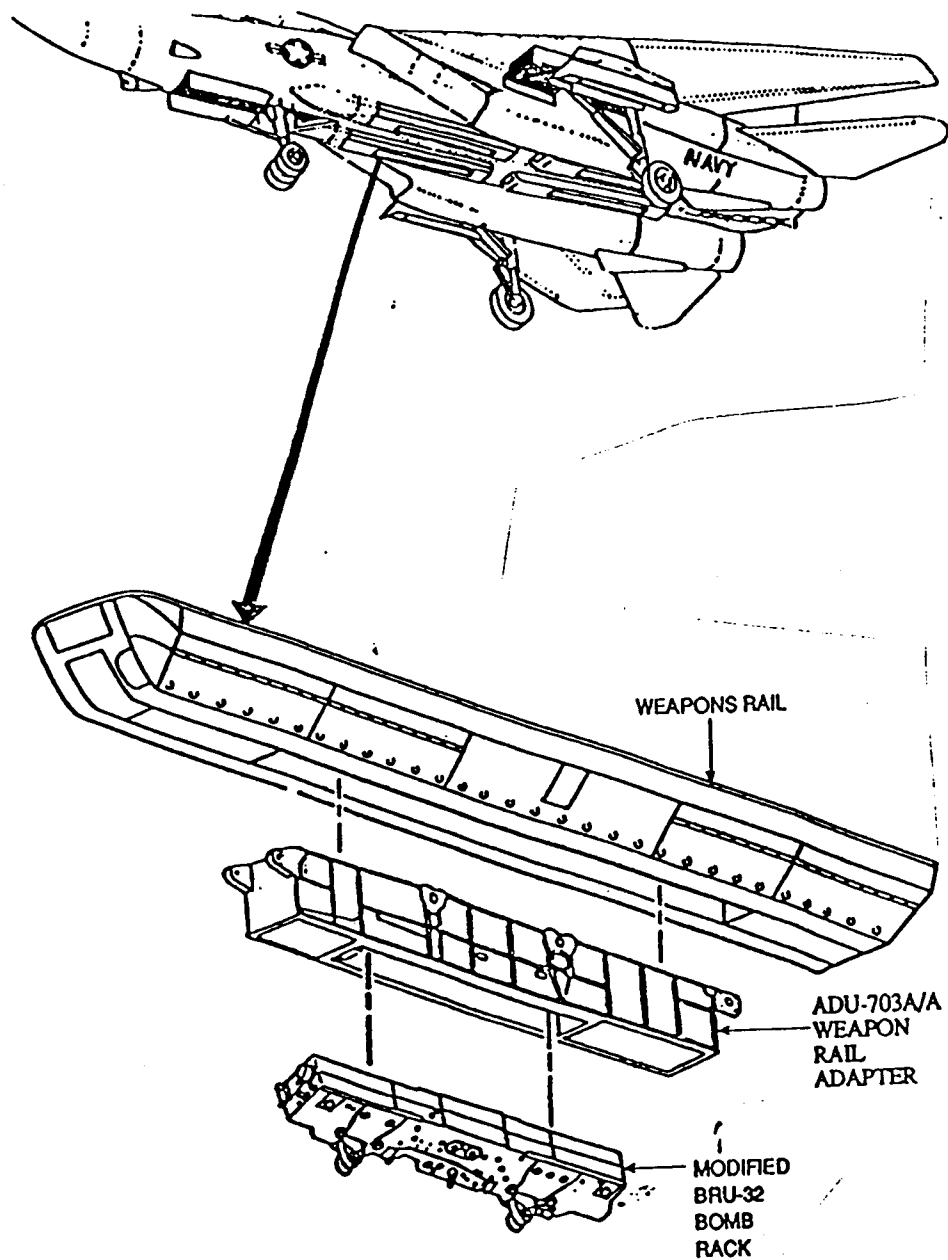


FIGURE 7
F-14 FUSELAGE WEAPON SUSPENSION EQUIPMENT

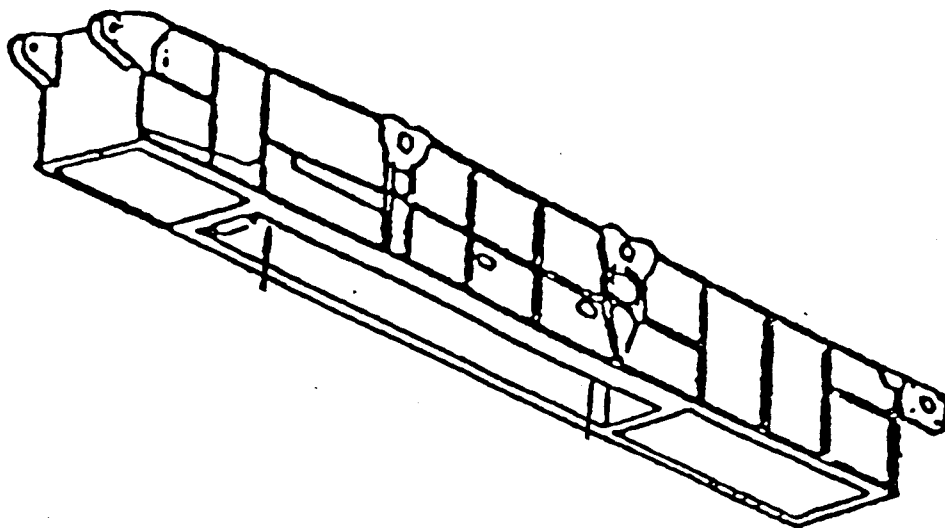


FIGURE 8
ADU-703A/A ADAPTER

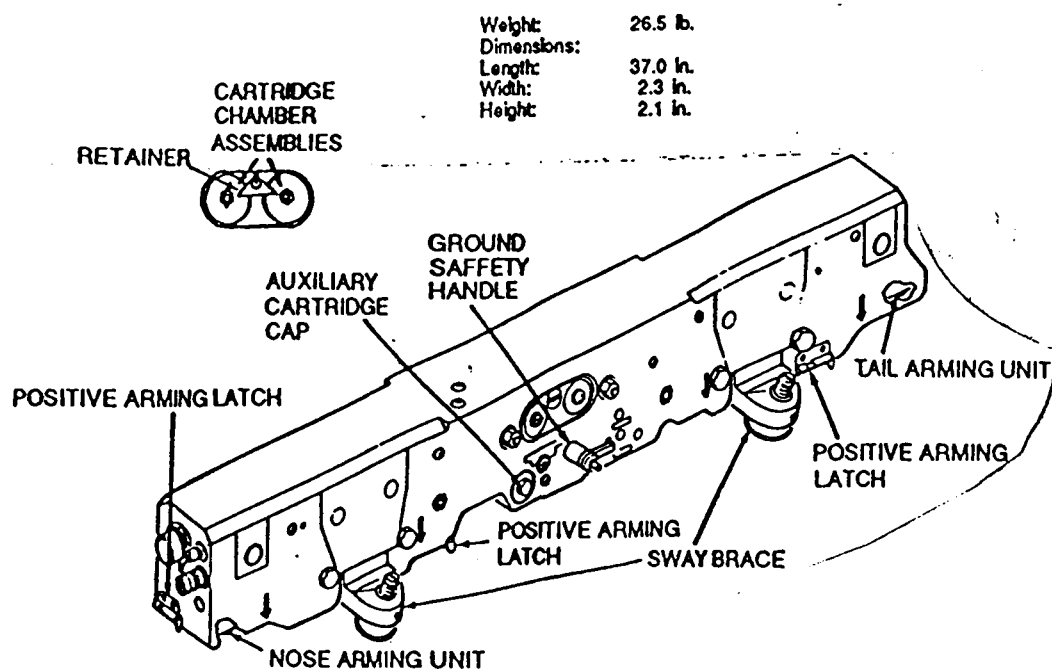


FIGURE 9
BRU-32/A BOMB RACK

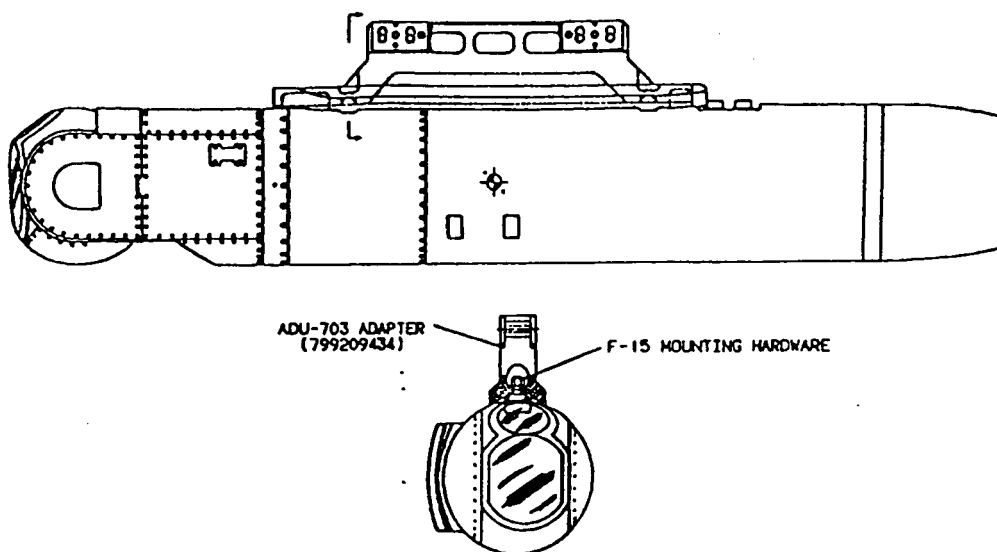


FIGURE 10
ADU-703 LANTIRN ADAPTER

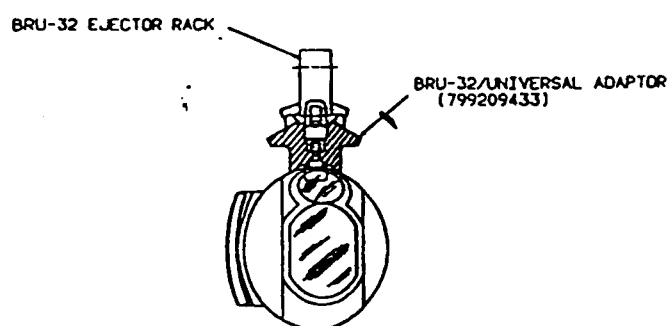
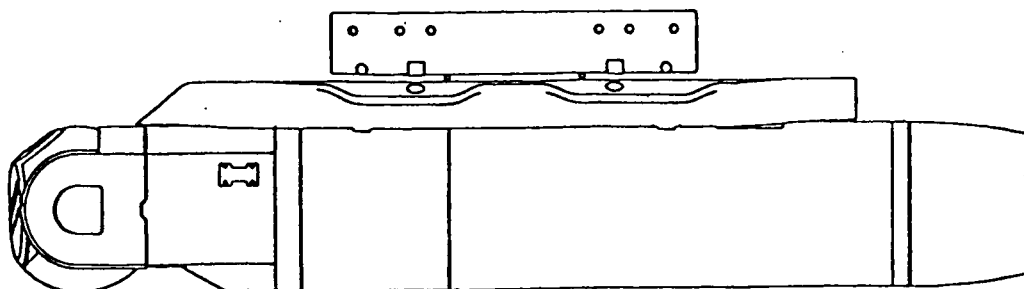
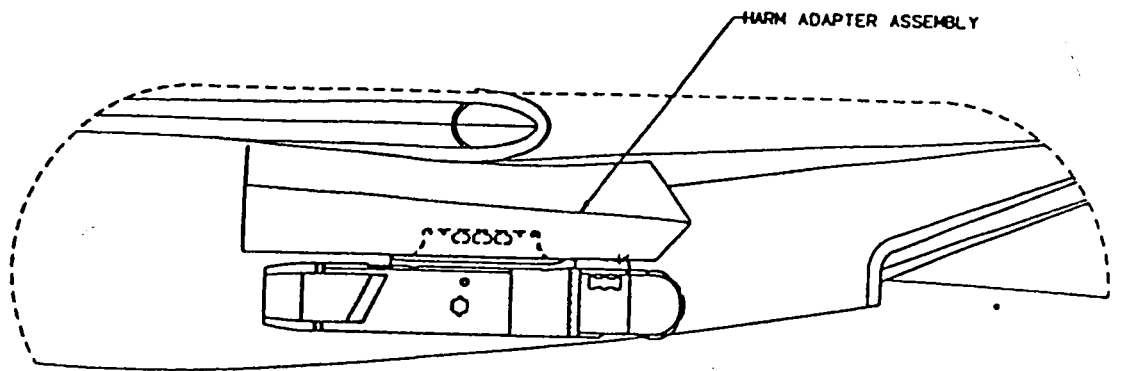


FIGURE 11
BRU-32 UNIVERSAL ADAPTER



799209434 ADAPTER

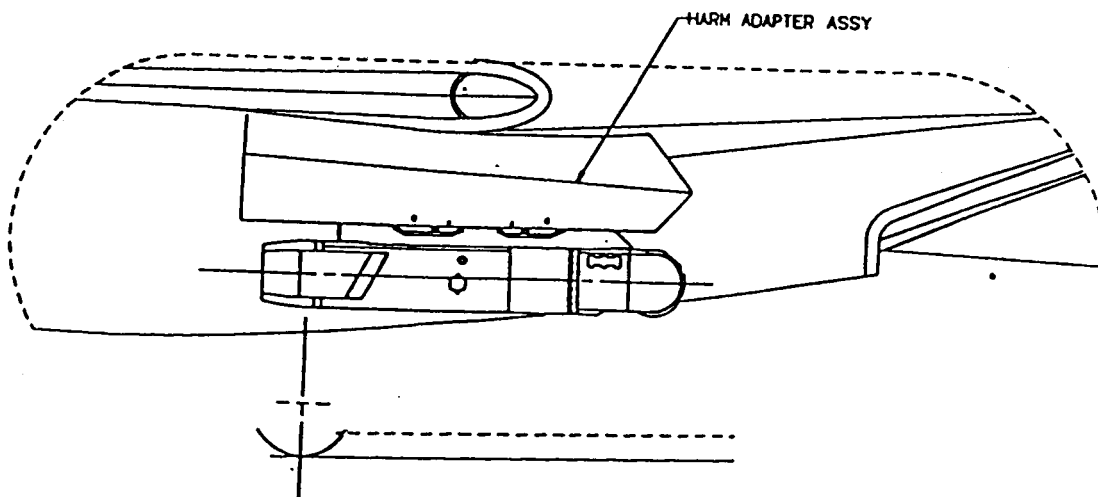


FIGURE 12
HIGH ANTI-RADIATION MISSILE (HARM) ADAPTER

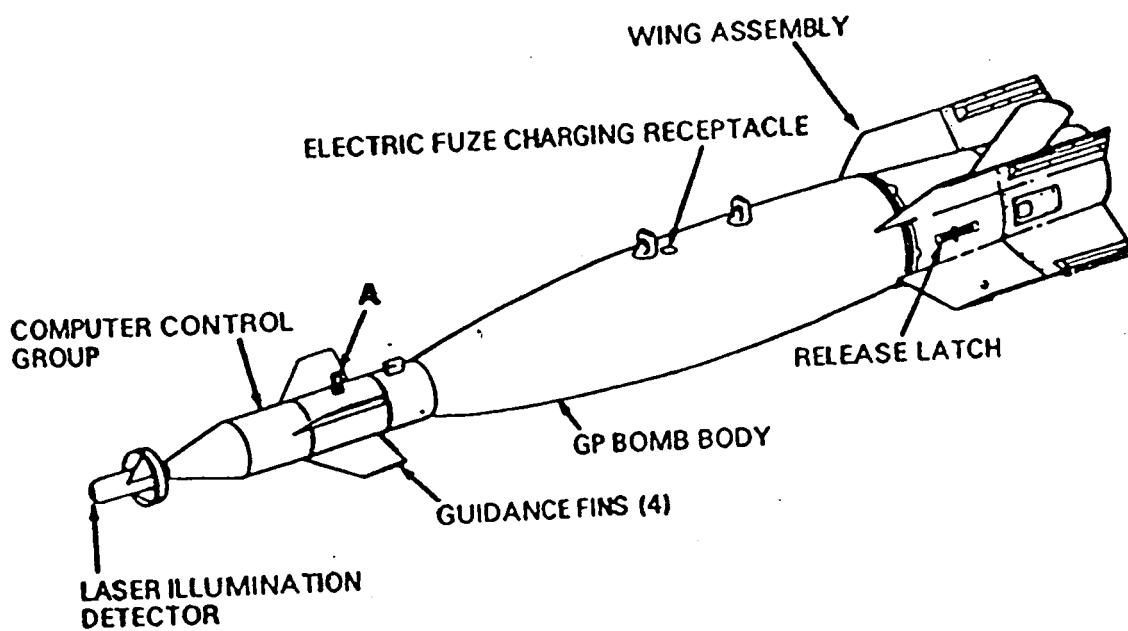


FIGURE 13
GBU-10 BOMB UNIT

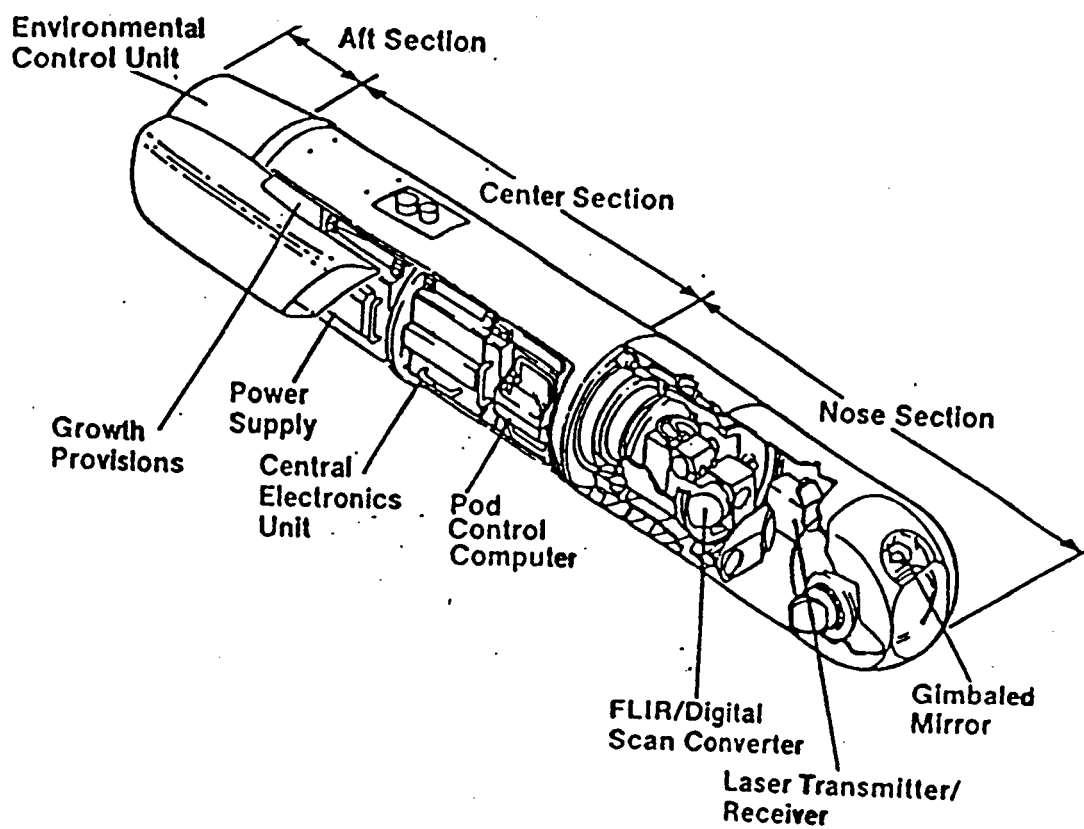


FIGURE 14
LANTIRN TARGETING POD

POWER - LOCKING TOGGLE SWITCH CLOSSES RELAY FOR AC/DC POD POWER.

MODE - LOCKING TOGGLE SWITCH COMMANDS POD TO STOW OR UNSTOW GIMBAL.

FOV - SWITCH SELECTION FOR WIDE OR NARROW FIELD OF VIEW.

IBIT - MOMENTARY PUSH BUTTON SWITCH FOR COMMANDING IBIT.

LOS - MOMENTARY PUSH BUTTON TO COMMAND THE POD TO CHANGE DEPRESSION ANGLES.

POD OVRTMP - LED INDICATOR FOR OVERTEMPERATURE CONDITION.

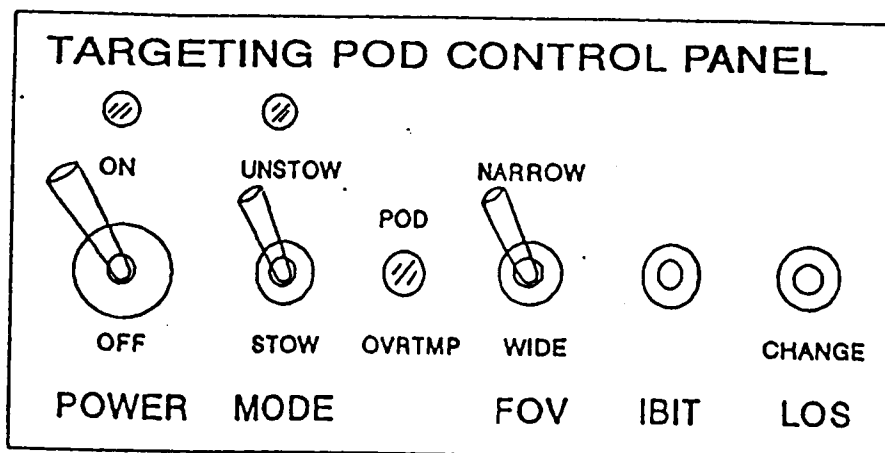


FIGURE 15
LANTIRN TARGETING POD CONTROL PANEL

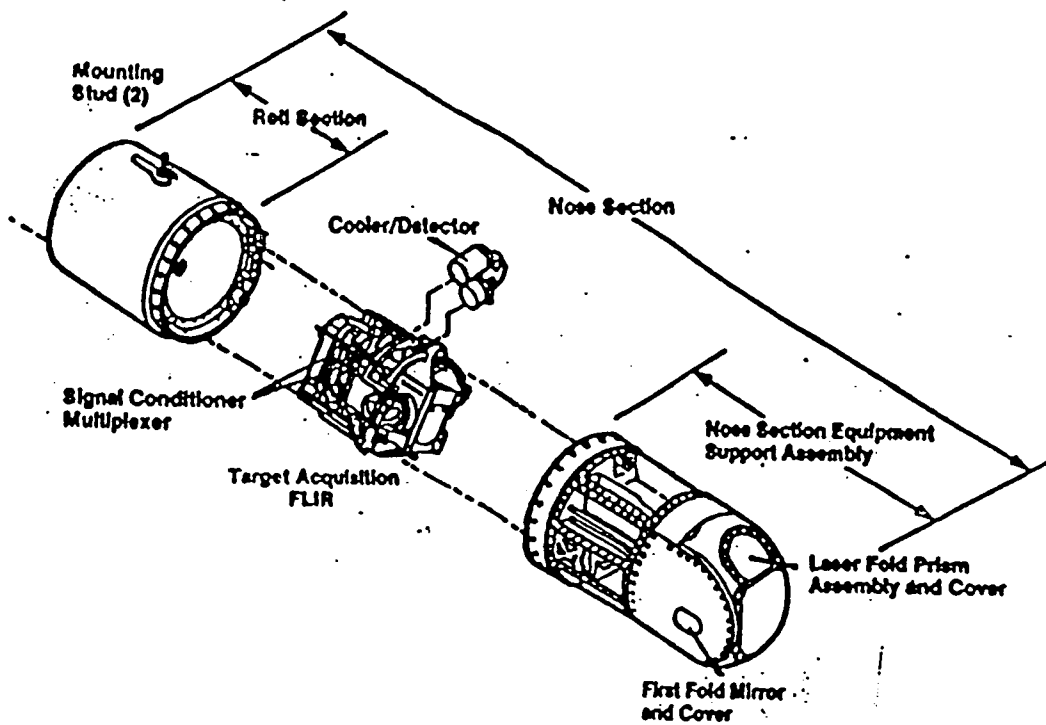


FIGURE 16
LANTIRN TARGETING POD NOSE SECTION

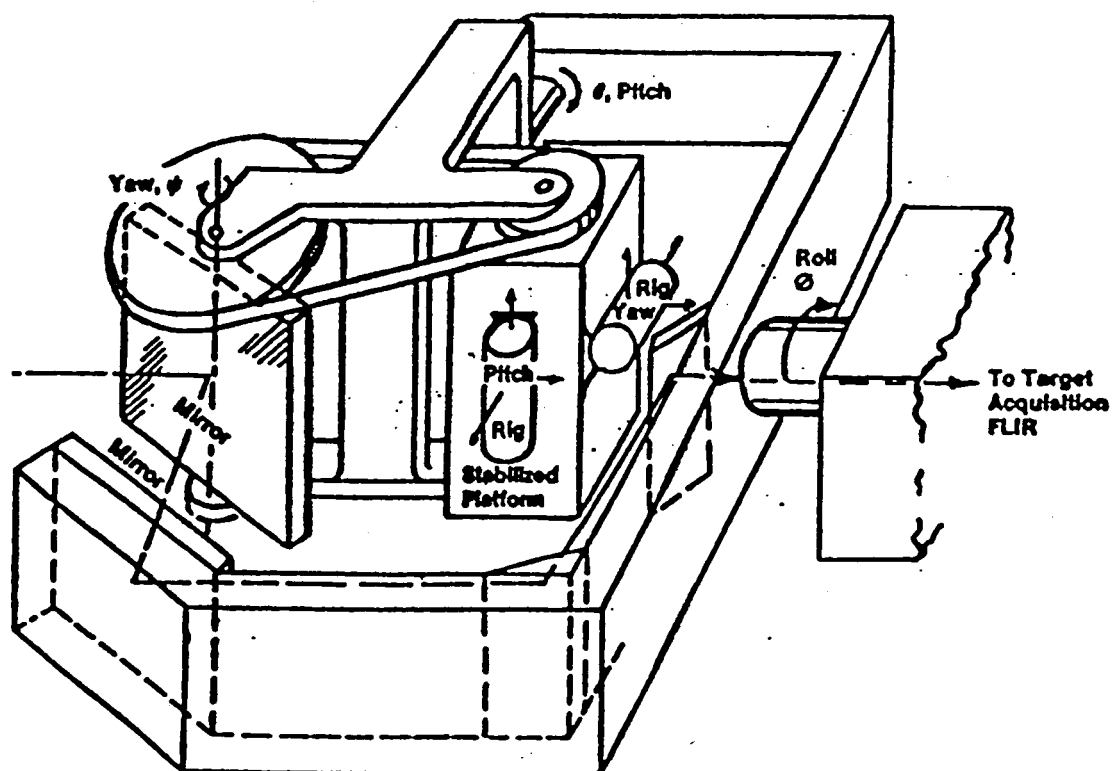


FIGURE 17
LANTIRN TARGETING POD GIMBAL ASSEMBLIES

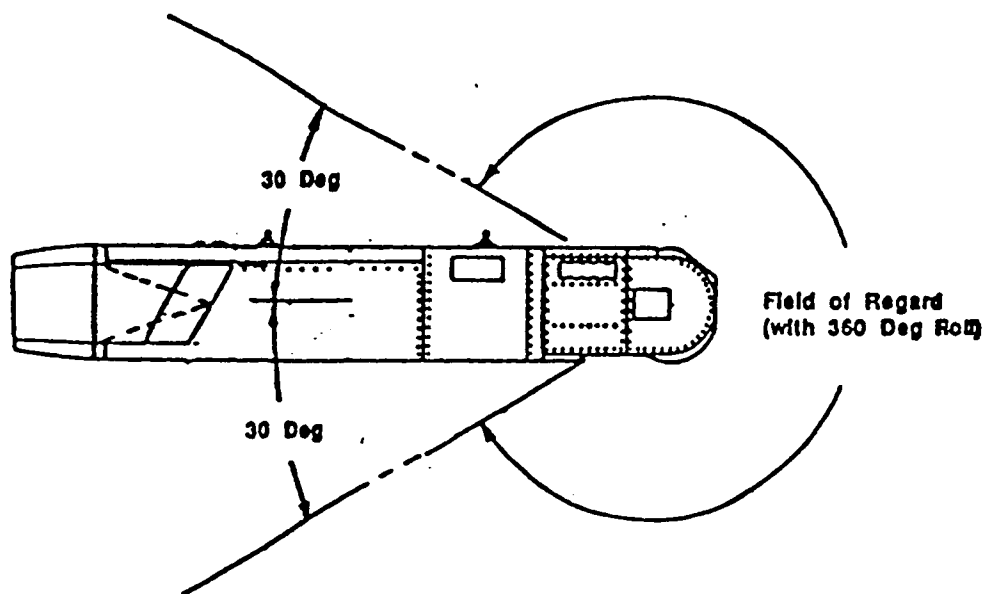
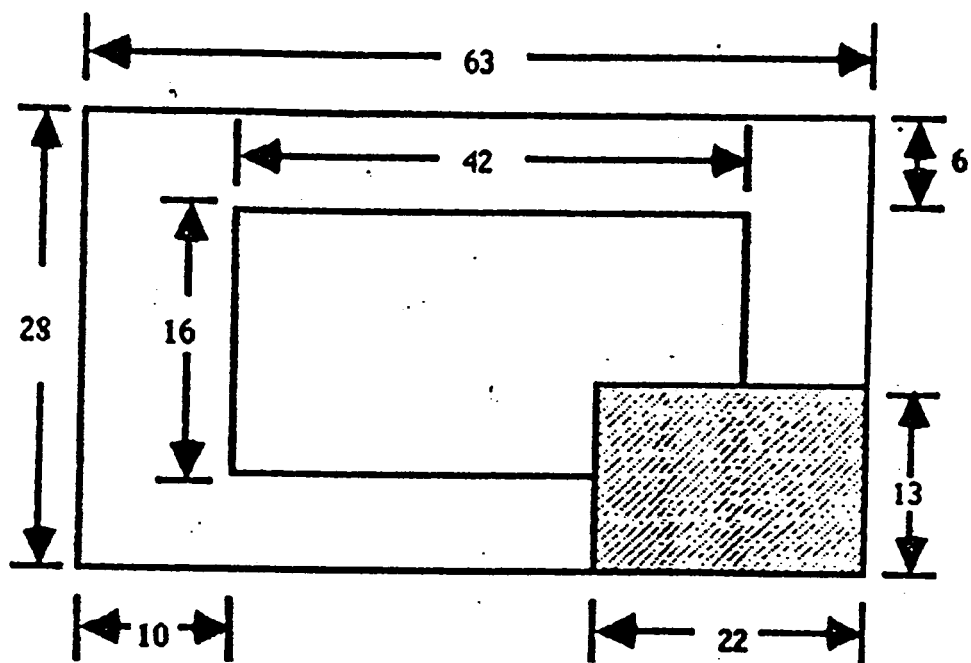
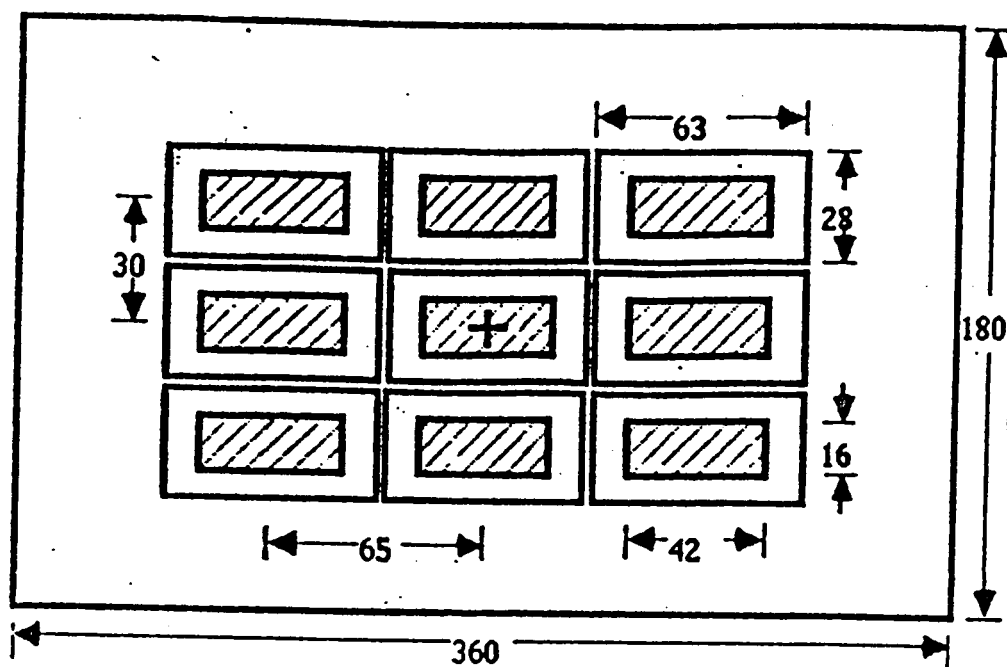


FIGURE 18
LANTIRN TFLIR DESIGNED FIELD OF REGARD



Note: Numbers shown represent numbers of pixels or lines

FIGURE 19
LANTIRN TFLIR TRACKER AREAS OF INTEREST (AOI)

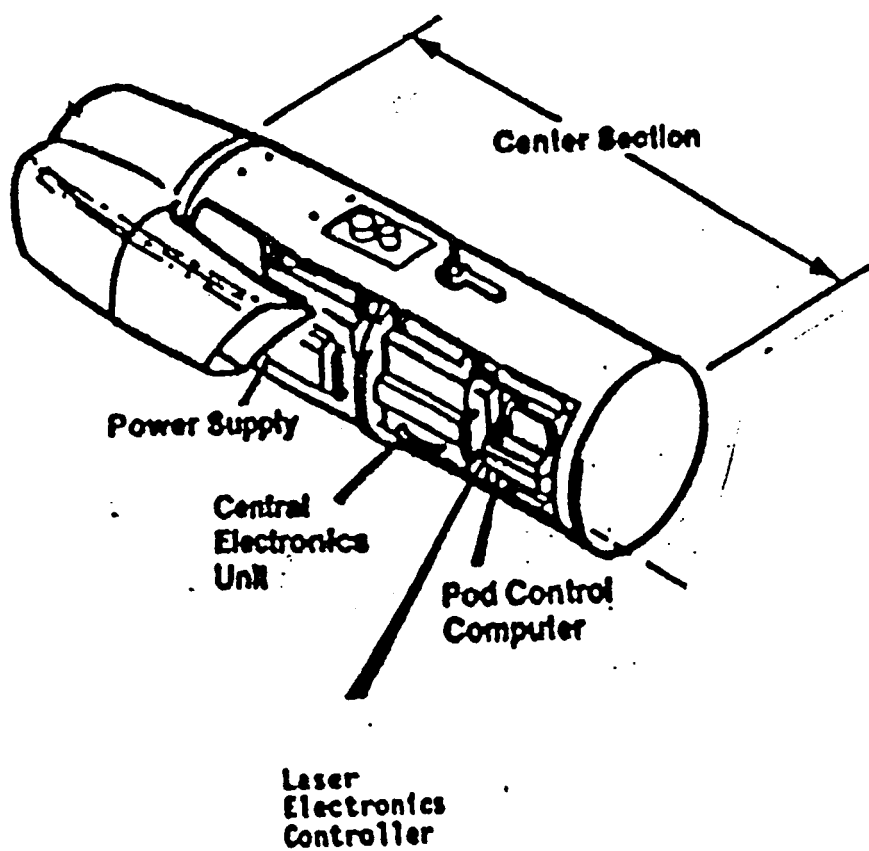


FIGURE 20
LANTIRN TFLIR CENTER SECTION

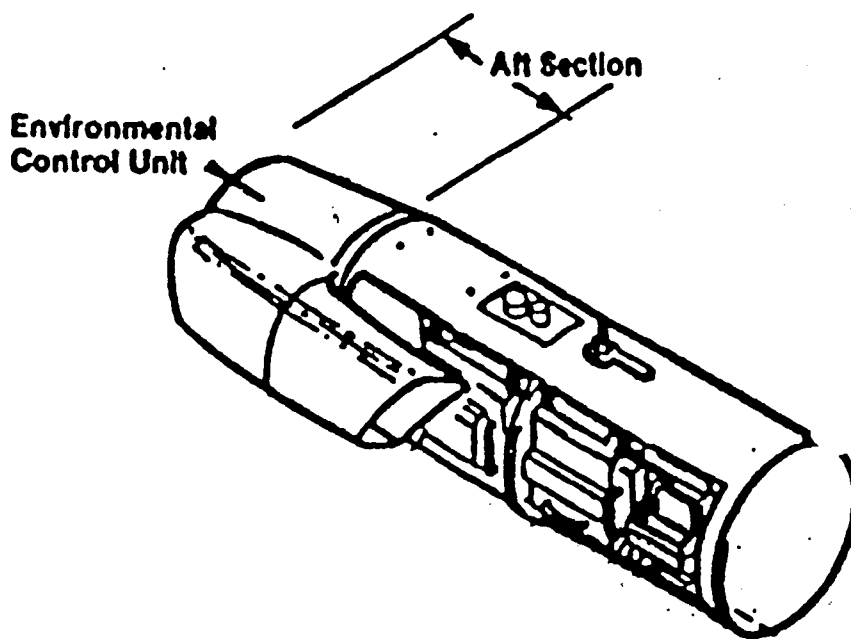


FIGURE 21
LANTIRN TFLIR AFT SECTION

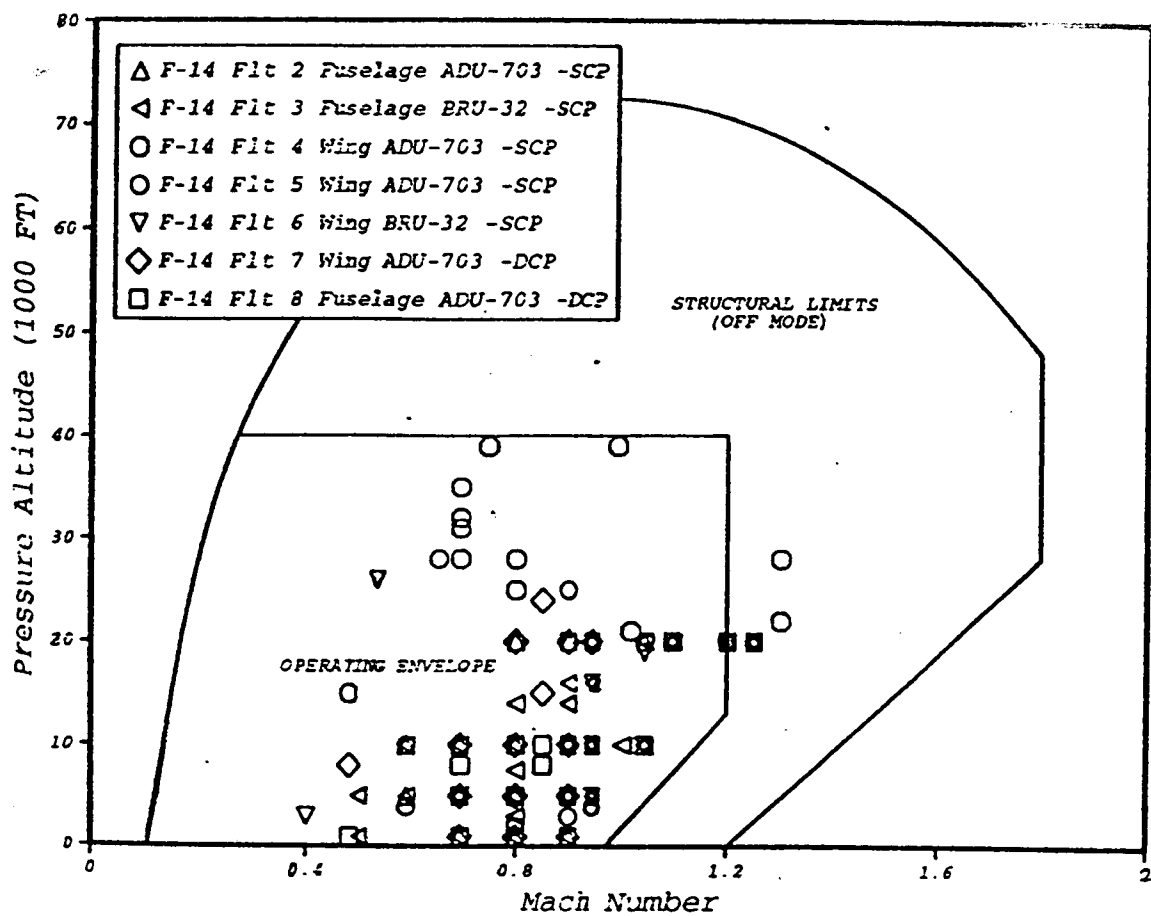


FIGURE 22
LANTIRN/F-14 DATA POINTS

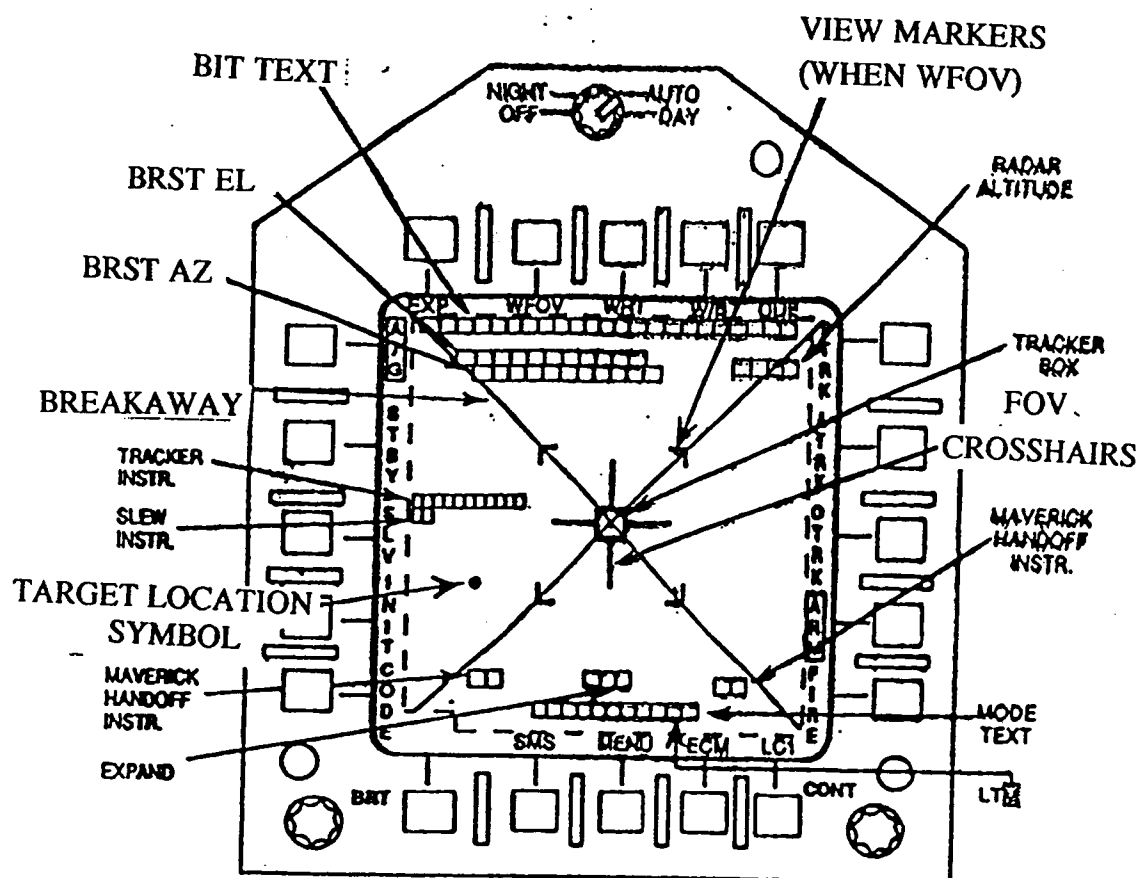
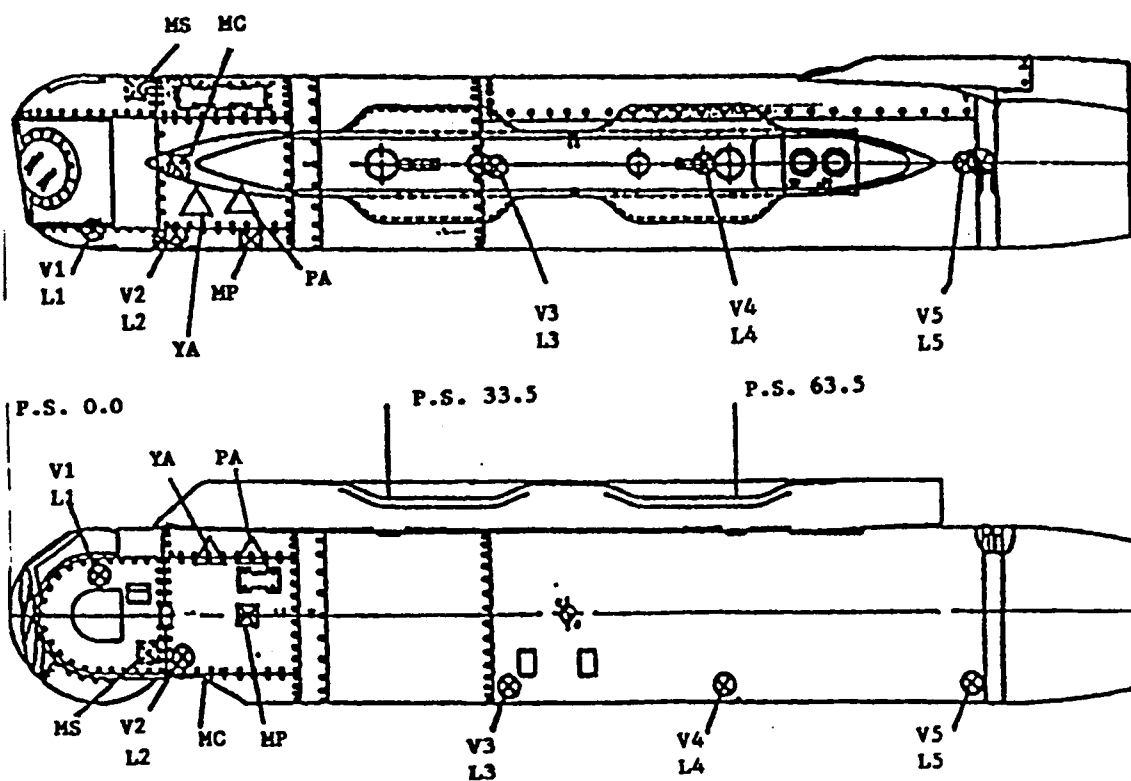


FIGURE 23
LANTIRN TFLIR DISPLAY



Note: Refer to Appendix C, Table II for legend

FIGURE 24
LANTIRN POD INSTRUMENTATION RECEIVER PLACEMENT

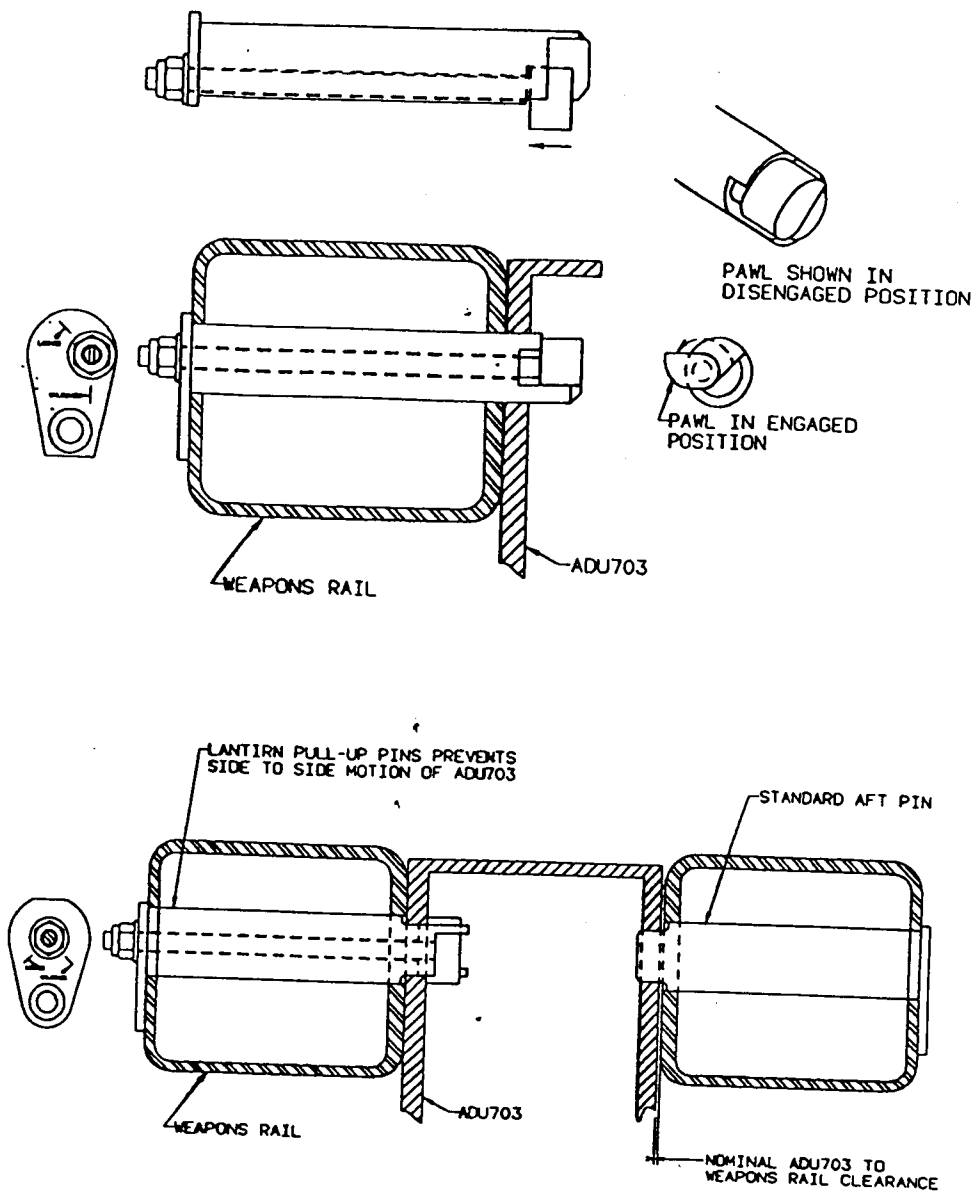


FIGURE 25
LANTIRN ADU-703 INTERFACE TIGHTENING HARDWARE

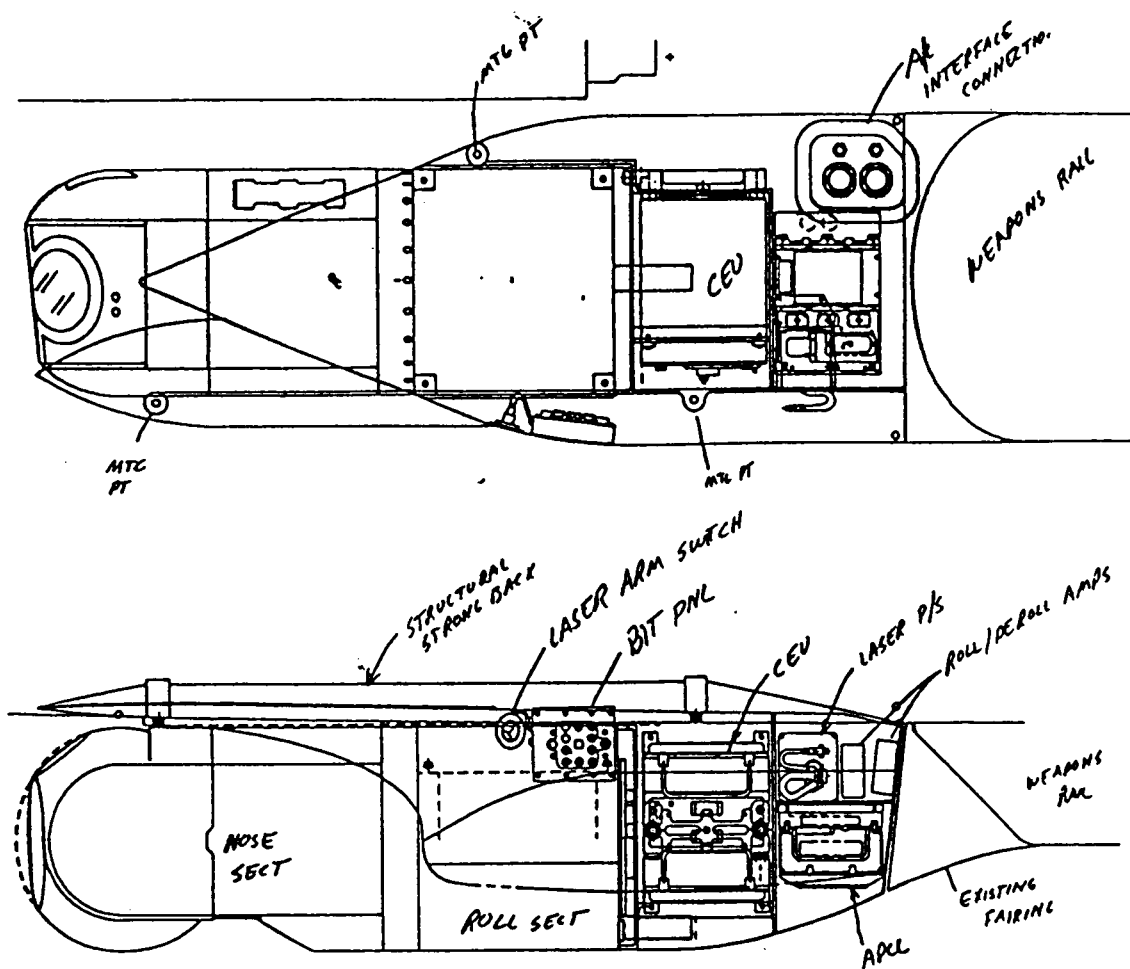


FIGURE 26
PROPOSED EMBEDDED LANTIRN TFLIR CONFIGURATION

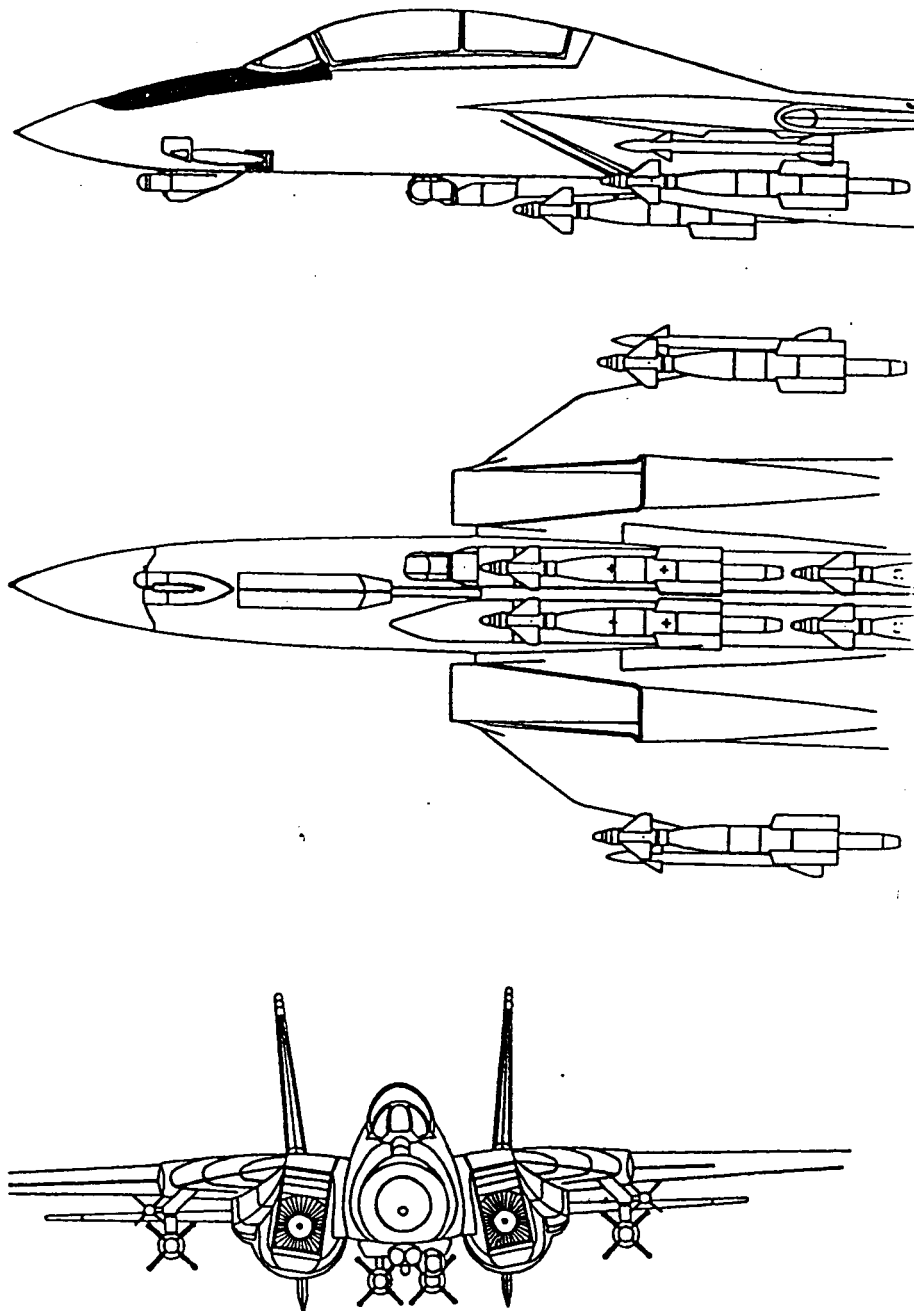


FIGURE 27
EMBEDDED TFLIR OPTICS POSITIONING

TABLES

Table I
LANTRN/F-14 TEST LOADINGS

FLIGHT #	1	2	3	4	5	6	7	8
DATE	5 Oct 93	7 Oct 93	8 Oct 93	28 Oct 93	1 Nov 93	2 Nov 93	7 Nov 93	8 Nov 93
LANTRN Station	Fuselage Station 6	Fuselage Station 6	Fuselage Station 6	Wing Station 8	Wing Station 8	Wing Station 8	Wing Station 8	Fuselage Station 6
LANTRN Mount	MMTI ADU-703 Pylon	MMTI ADU-703 Pylon	MMTI BRU-32 Bomb Rack Pylon	MMTI ADU-703 Pylon	MMTI ADU-703 Pylon	MMTI BRU-32 Bomb Rack Pylon	MMTI ADU-703	MMTI ADU-703 Pylon
Chin Pod	Single	Single	Single	Single	Single	Single	Dual	Dual
A/C Stores								
Station 1	-	-	-	-	-	-	-	-
Station 2	-	-	-	-	-	-	-	-
Station 3	-	-	-	-	-	-	-	-
Station 4	-	-	-	-	-	-	-	-
Station 5	-	-	-	-	-	-	-	-
Station 6	LANTRN	LANTRN	LANTRN	-	-	-	BRU-32	LANTRN
Station 7	-	-	Fuel Tank	Fuel Tank LANTRN	Fuel Tank LANTRN	Fuel Tank LANTRN	Fuel Tank LANTRN	Fuel Tank
Station 8	-	-	-	-	-	-	-	-

TABLE II
BREAKOUT OF LANTIRN TFLIR INSTRUMENTATION DATA

LABEL	DESCRIPTION LOCATION	FM CALIBRATION (cal 40% dev)	ANALOG TAPE FREQUENCY RESPONSE	ANALOG TAPE CHANNEL/ FORMAT	FREQUENCY RESPONSE	DATA SAMPLE RATE
			Hz	(1-14)	Hz	sec ⁻¹
L1	Linear Accelerometer-Lateral Axis Nose Section Port Ear	+/- 30 g	2000	9 (FM/WB 1)	2000	8192
V1	Linear Accelerometer-Vertical Axis Nose Section Port Ear	+/- 30 g	2000	10 (FM/WB 1)	2000	8192
L2	Linear Accelerometer-Lateral Axis Laser Compartment	+/- 30 g	2000	4 (MPX-1) (IRIG-B 3B)	2000	8192
V2	Linear Accelerometer-Vertical Axis Laser Compartment	+/- 30 g	2000	11 (FM/WB 1)	2000	8192
L3	Linear Accelerometer-Lateral Axis Center Section Fwd	+/- 30 g	2000	4 (MPX-1) (IRIG-B 5B)	2000	8192
V3	Linear Accelerometer-Vertical Axis Center Section Fwd	+/- 30 g	2000	4 (MPX-1) (IRIG-B 7B)	2000	8192
L4	Linear Accelerometer-Lateral Axis Center Section Mid	+/- 30 g	2000	4 (MPX-1) (IRIG-B 9B)	2000	8192
V4	Linear Accelerometer-Vertical Axis Center Section Mid	+/- 30 g	2000	5 (MPX-2) (IRIG-B 5B)	2000	8192
L5	Linear Accelerometer-Lateral Axis Center Section Aft	+/- 30 g	2000	5 (MPX-2) (IRIG-B 9B)	2000	8192
V5	Linear Accelerometer-Vertical Axis Center Section Aft	+/- 30 g	2000	5 (MPX-2) (IRIG-B 7B)	2000	8192
A5	Linear Accelerometer-Axial Axis Center Section Aft	+/- 30 g	2000	5 (MPX-2) (IRIG-B 11B)	2000	8192
YR	Gyro Error Signal - Yaw Axis	+/- 799 μ rad	1000	4 (MPX-1) (IRIG-B 11B)	500	2048
PR	Gyro Error Signal - Pitch Axis	+/- 936 μ rad	1000	5 (MPX-2) (IRIG-B 3B)	500	2048
YA	Angular Accelerometer - Yaw Axis	+/- 100 rad/s ²	500	7 (FM/WB 1)	500	2048
PA	Angular Accelerometer - Pitch Axis	+/- 100 rad/s ²	500	8 (FM/WB 1)	500	2048
MS	Acoustic Microphone Starboard Nose Section	0.823 psi 166 dB *	5000	14 (FM/WB 1)	5000	20480
MC	Acoustic Microphone Transition Cavity	1.30 psi 170 dB	5000	13 (FM/WB 1)	5000	20480
MP	Acoustic Microphone Port Nose Section	0.823 psi 166 dB	5000	12 (FM/WB 1)	5000	20480

*Calibration for MS was changed to 1.6 psi at 40% carrier deviation after flight 3.

TABLE III
GENERALIZED COMPARISON OF F-14 VIBRATION DATA WITH THE F-15E
OPERATIONAL SPECIFICATION

Measurement Parameter	Flight 2 Fuselage ADU-703 MMTI Pylon Single Chin	Flight 3 Fuselage BRU-32 MMTI B.R. Pylon Single Chin	Flight 4 Wing HARM MMTI Pylon Single Chin	Flight 5 Wing HARM MMTI Pylon Single Chin	Flight 6 Wing HARM BRU-32 B.R. Pylon Single Chin	Flight 7 Wing HARM MMTI Pylon Dual Chin	Flight 8 Fuselage ADU-703 MMTI Pylon Dual Chin
Nose Section Accelerometers							
L1	-	-	-	-	-	-	-
L2	-	-	-	-	-	-	-
V2	-	-	-	-	Slightly Exceeds	-	-
Center Section Accelerometers							
L3	-	-	-	-	-	-	-
V3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AR Section Accelerometers							
L5	-	-	Slightly Exceeds	Exceeds	Exceeds	Slightly Exceeds	Slightly Exceeds
V5	Slightly Exceeds	-	Slightly Exceeds	Exceeds	Exceeds	Exceeds	Slightly Exceeds
A5	N/A	N/A	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds
Acoustic Microphones							
MP	-	-	-	-	-	-	-
MS	-	-	-	-	-	-	-
MC	-	-	-	-	-	-	-
N/A= Not Available, - implies F-14 data is less than F-15/F-16 operational limits							

FIGURES

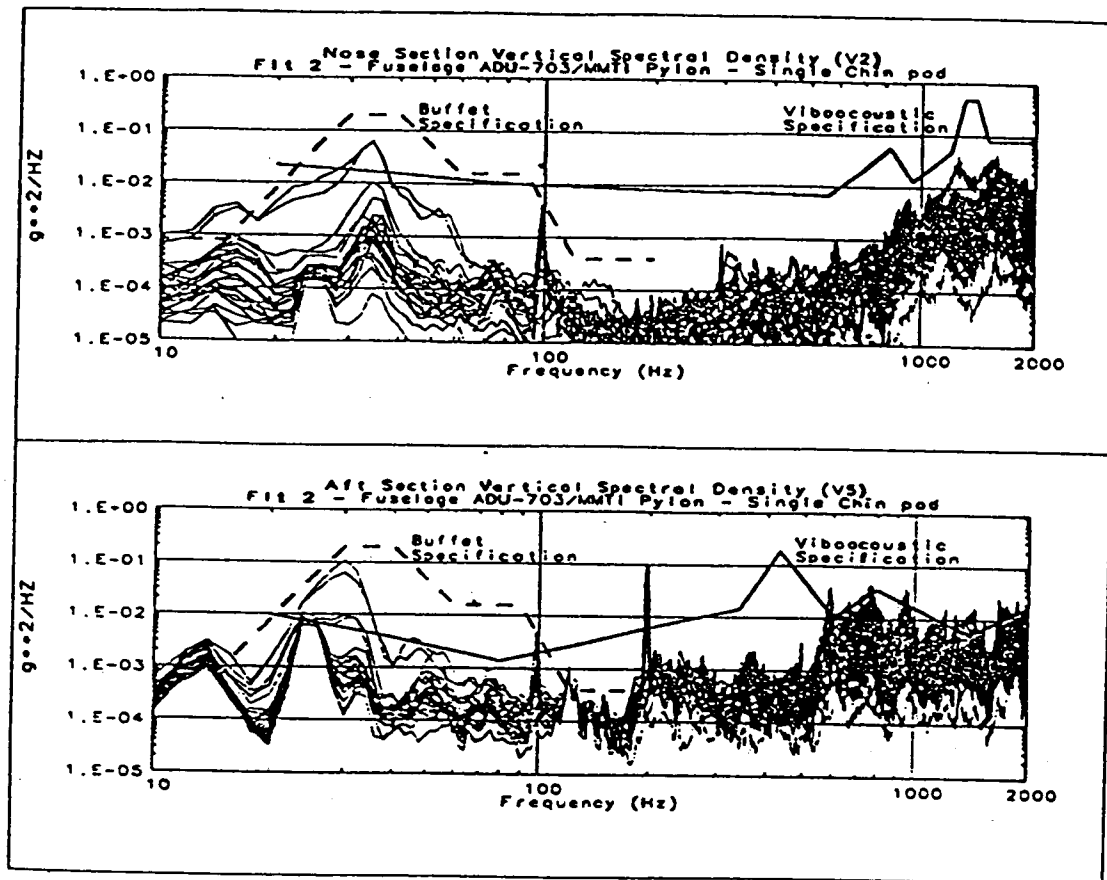


FIGURE 1
VERTICAL VIBRATION LOADS FOR A FUSELAGE MOUNTED TFLIR USING
THE ADU-703/MMTI ADAPTER

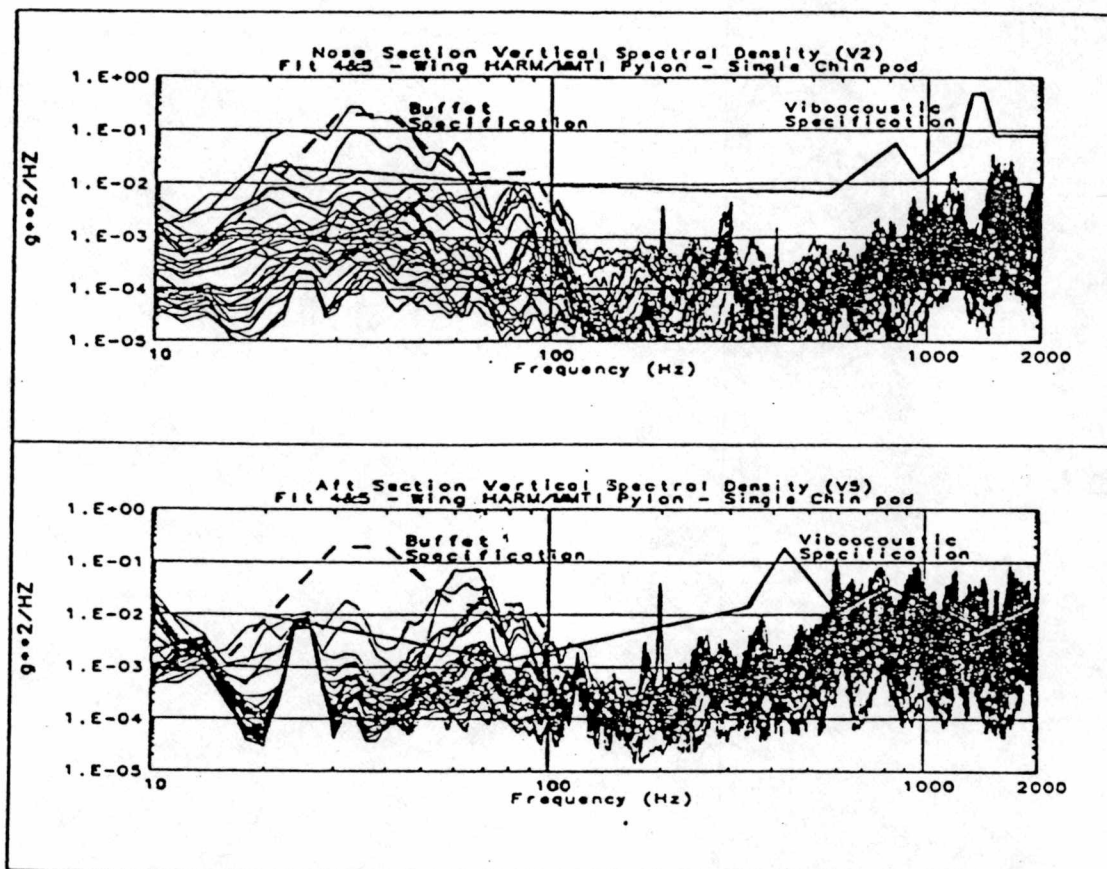


FIGURE 2
 VERTICAL VIBRATION LOADS FOR A WING MOUNTED TFLIR USING THE
 ADU-703/MMTI ADAPTER

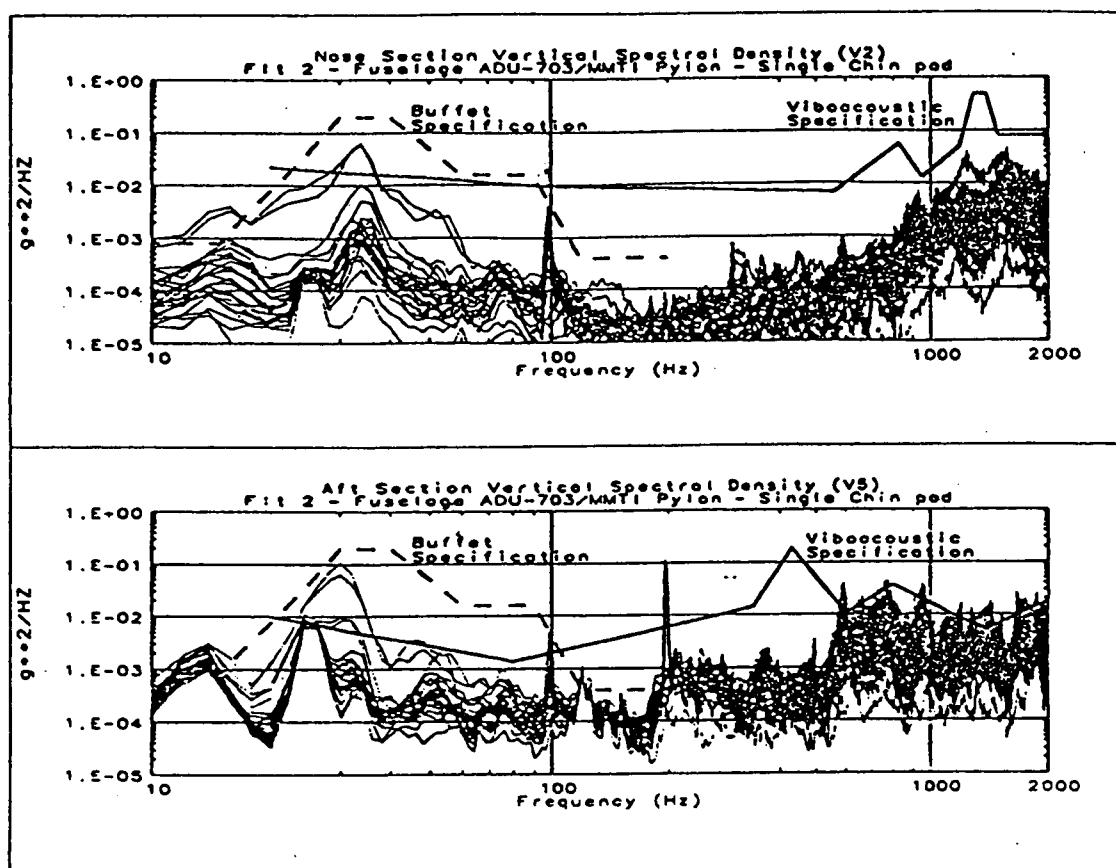


FIGURE 3
NOSE SECTION VERTICAL VIBRATION LOADS FOR A FUSELAGE
MOUNTED POD USING THE ADU-703/MMTI ADAPTER

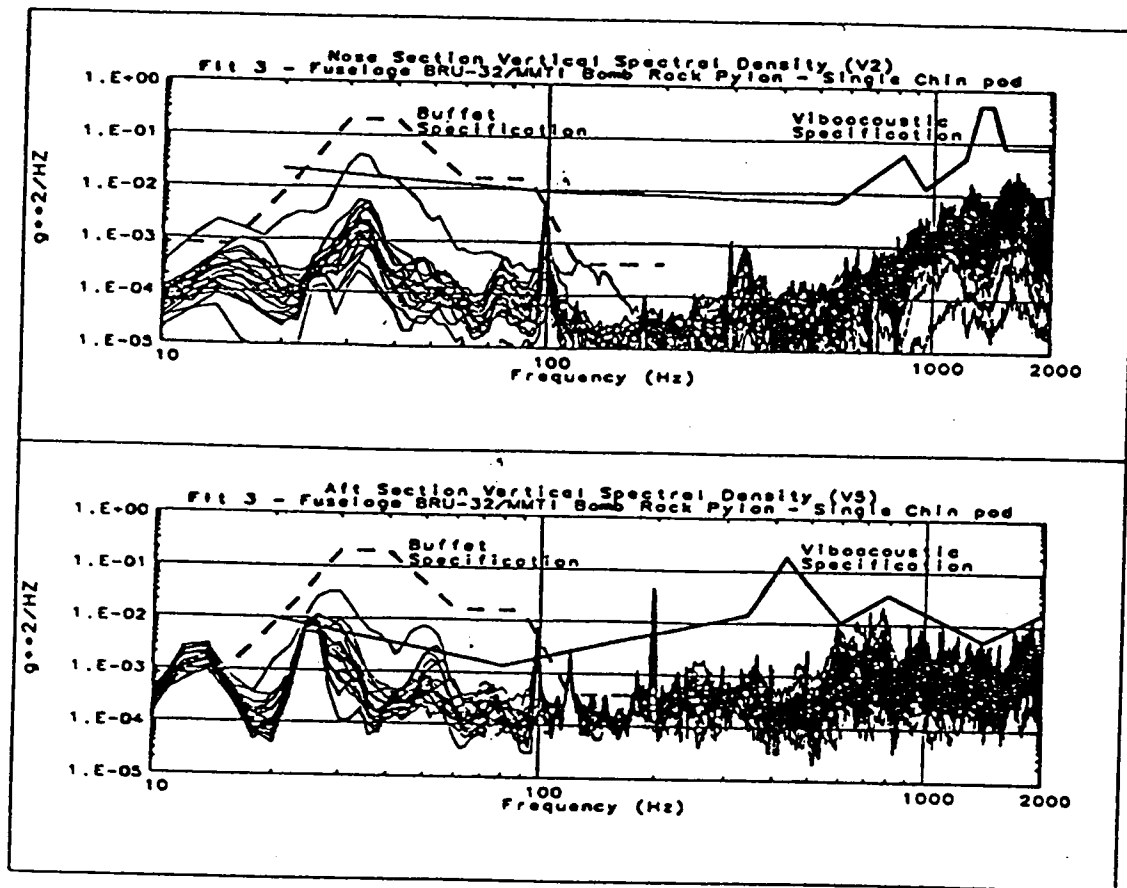


FIGURE 4
NOSE SECTION VERTICAL VIBRATION LOADS FOR A FUSELAGE
MOUNTED POD USING THE BRU-32 UNIVERSAL ADAPTER

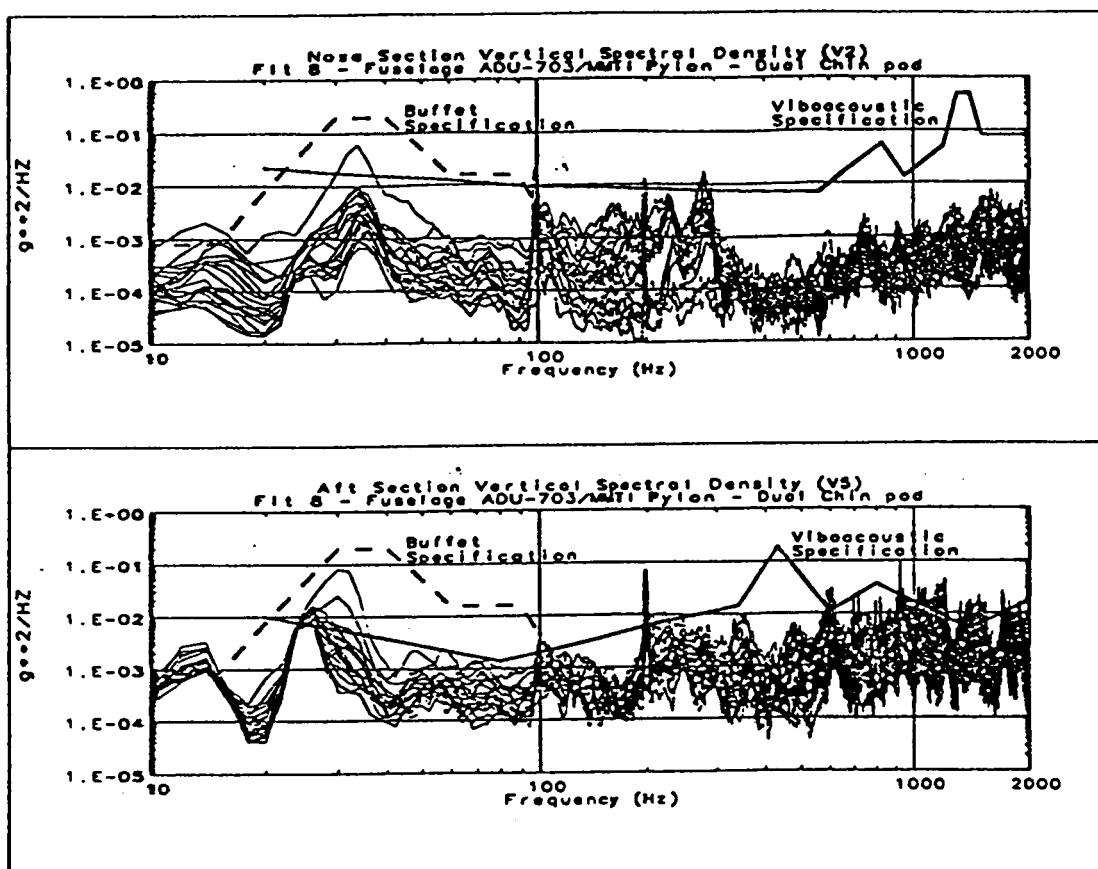


FIGURE 5
 VIBRATION LOADS FOR A FUSELAGE MOUNTED TFLIR USING THE ADU-703/MMTI ADAPTER (F-14 CONFIGURED WITH DUAL CHIN POD)

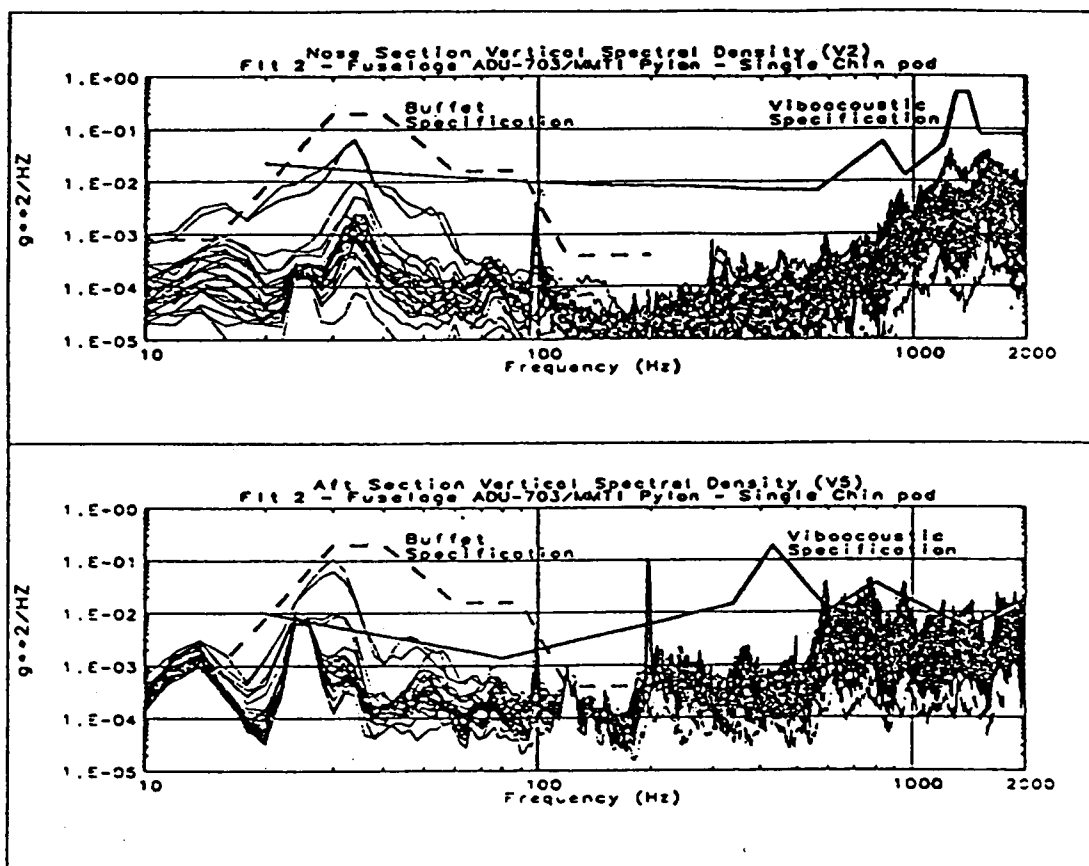


FIGURE 6
VIBRATION LOADS FOR A FUSELAGE MOUNTED TFLIR USING THE ADU-703/MMTI ADAPTER (F-14 CONFIGURED WITH SINGLE CHIN POD)

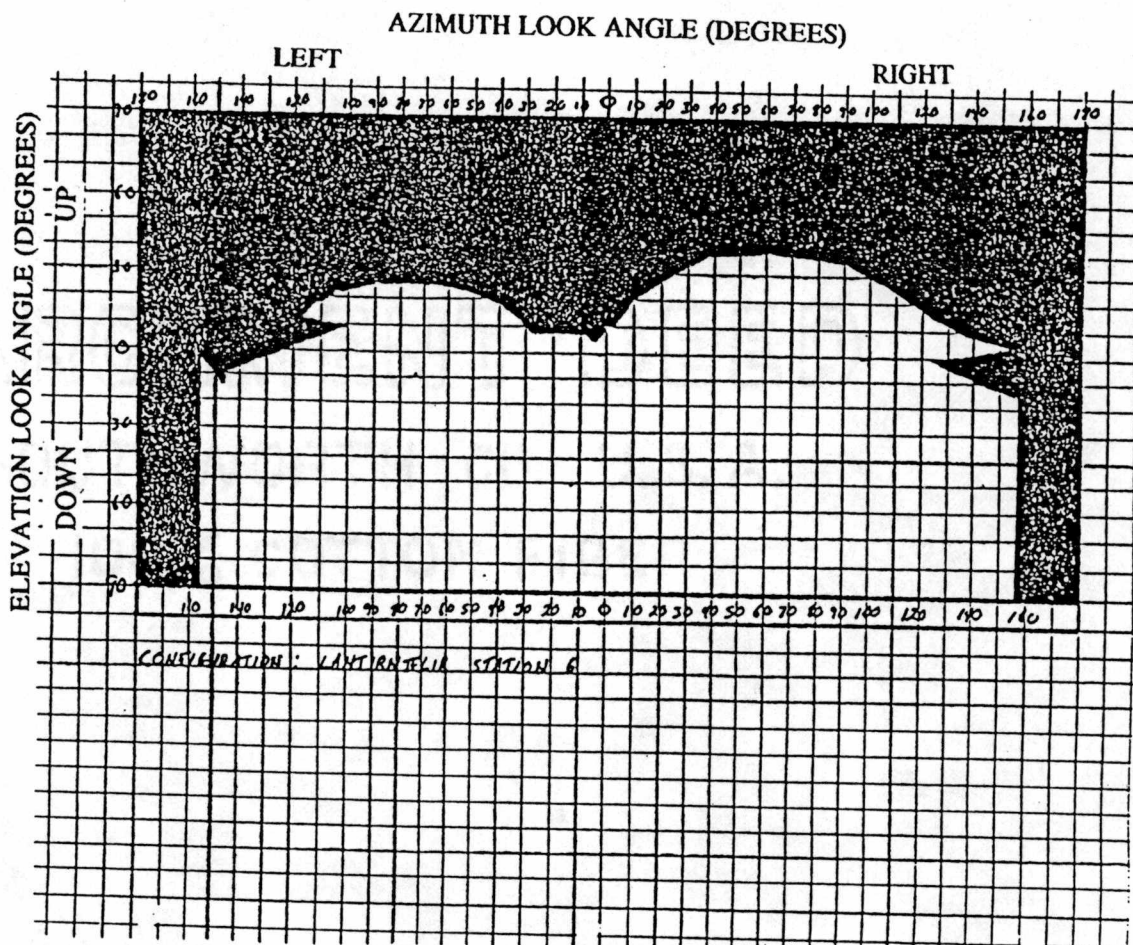


FIGURE 8
F-14 TOTAL VISION PLOT WITH THE TFLIR INSTALLED ON STATION 6.
TANKS INSTALLED ON STATIONS 2 AND 7

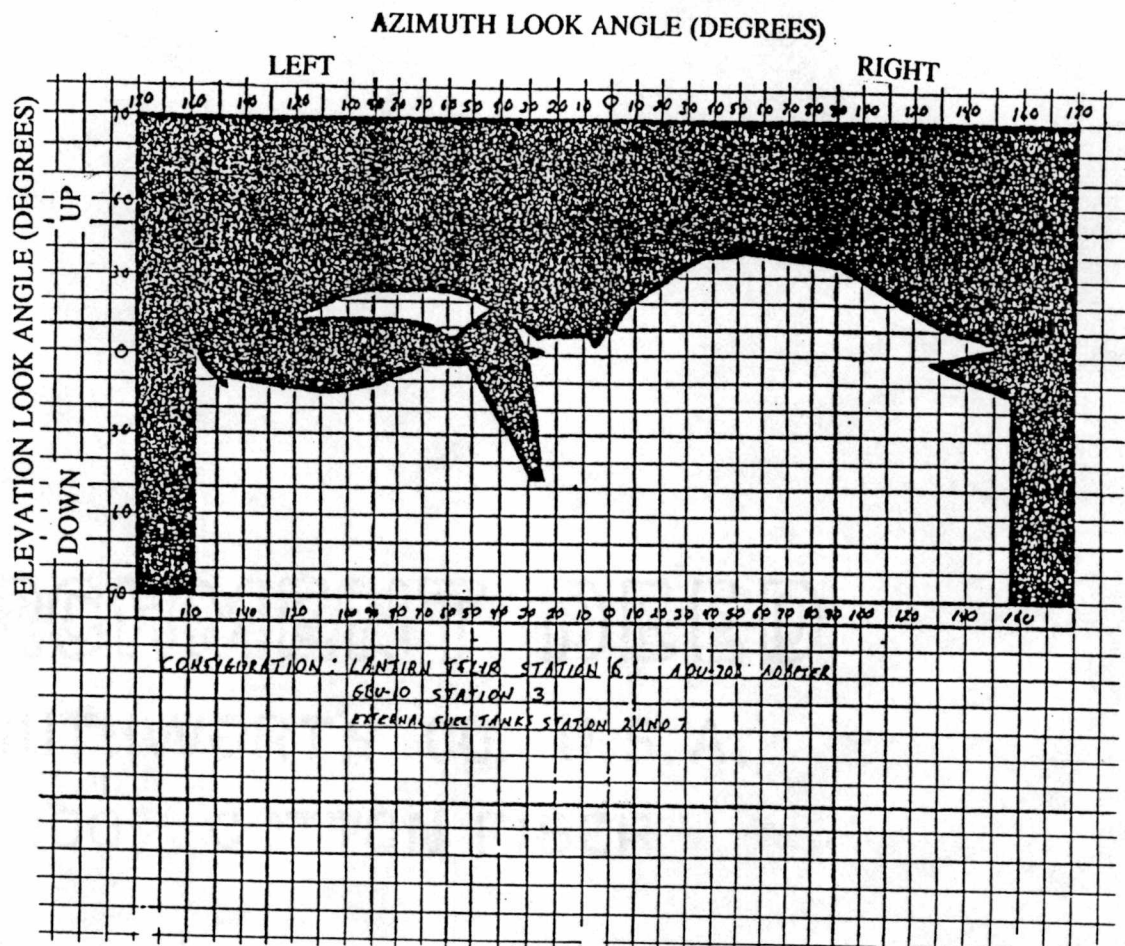


FIGURE 9
F-14 TOTAL VISION PLOT WITH THE TFLIR INSTALLED ON STATION 6.
TANKS INSTALLED ON STATION 2 AND 7. GBU-10 INSTALLED ON STATION
3

VITA

Brian M. Kocher was born in Winnemucca, Nevada, on October 2, 1963. He graduated from Blaine High School (Blaine, Washington) in June 1981 and the following summer began studies at the University of Washington. In June 1985 he received his Bachelor of Science Degree in Aeronautics and Astronautics Engineering and upon graduation, was commissioned as an Ensign in the United States Navy. Brian underwent flight training at Pensacola Naval Air Station and when he received his wings, he was designated an F-14 Radar Intercept Officer (RIO). His first assignment was to Fighter Squadron Two where he deployed on two, six month deployments to the Western Pacific and Indian Ocean.

Brian completed training at the United States Naval Test Pilot School in July 1992 and reported to the Strike Aircraft Test Directorate, where he has been involved in numerous system test and evaluation projects on the F-14 Tomcat. He enrolled at the University of Tennessee Space Institute and earned his Master of Science Degree in Aviation Systems in December, 1994. His flight experience spans over 1500 hours in 27 different aircraft types and includes 175 combat hours during Operation Desert Storm.

He is currently assigned to Fighter Squadron 24 in San Diego, California.