CP 593

AGM-130 IMPROVED MODULAR INFRARED SENSOR (IMIRS) FLIGHT TEST

1st Lt Thomas A. Corej
Capt Keith J. Kosan
40th Flight Test Squadron/DOOB
505 W Choctawhatchee Ave Ste 1
Eglin AFB FL 32542-5722
USA

SUMMARY
The AGM-130/Improved Modular Infrared Sensor (IMIRS) weapon system is operationally compatible with the F-15E and F-111F launch platforms. The addition of a rocket motor to the GBU-15, making it an AGM-130, increases the standoff range of the AGM-130.

The IMIRS seeker is an infrared (IR) seeker for the AGM-130, and the AGM-130/IMIRS system provides sufficient resolution for target detection in day or night. Using a two-ship scenario (one weapon-carrying aircraft and one controlling aircraft), the controlling aircraft can stand off at an extended classified range and successfully guide the weapon to impact. The aimpoint update feature of the IMIRS seeker allows for small changes to be made in the aimpoint allowing for precisely attacking a specific point on a target. When the weapon systems officer (WSO) locks-on to a target, he can slew to refine the desired mean point of impact (DMPI) and then lock-on to the new DMPI without breaking the lock on the original aimpoint.

LIST OF SYMBOLS AND ACRONYMS

AFB	Air Force Base
AGL	above ground level
C^3	command, control, and communication
CCF	Centralized Control Facility
DMPI	desired mean point of impact
EMC	electromagnetic compatibility
EMI	electromagnetic interference
FOV	field of view
ft	feet
FTS	flight termination system
GWEF	Guided Weapons Evaluation Facility
IMIRS	Improved Modular Infrared Sensor
IMV	instrumented mock-up vehicle
in.	inches
IR	infrared
IRRTS	infrared resolution target set
KGS	knots groundspeed
km	kilometers
km/h	kilometers per hour
m	meters
mi	miles
MRTD	minimum resolvable temperature differential
NETD	noise equivalent temperature differential
nmi	nautical miles
SAM	surface-to-air missile
TIPS	Thermal Image Processing System
TM	telemetry
TSPI	time-space-position information
USAF	United States Air Force
WDL	weapon datalink
WSO	weapon systems officer

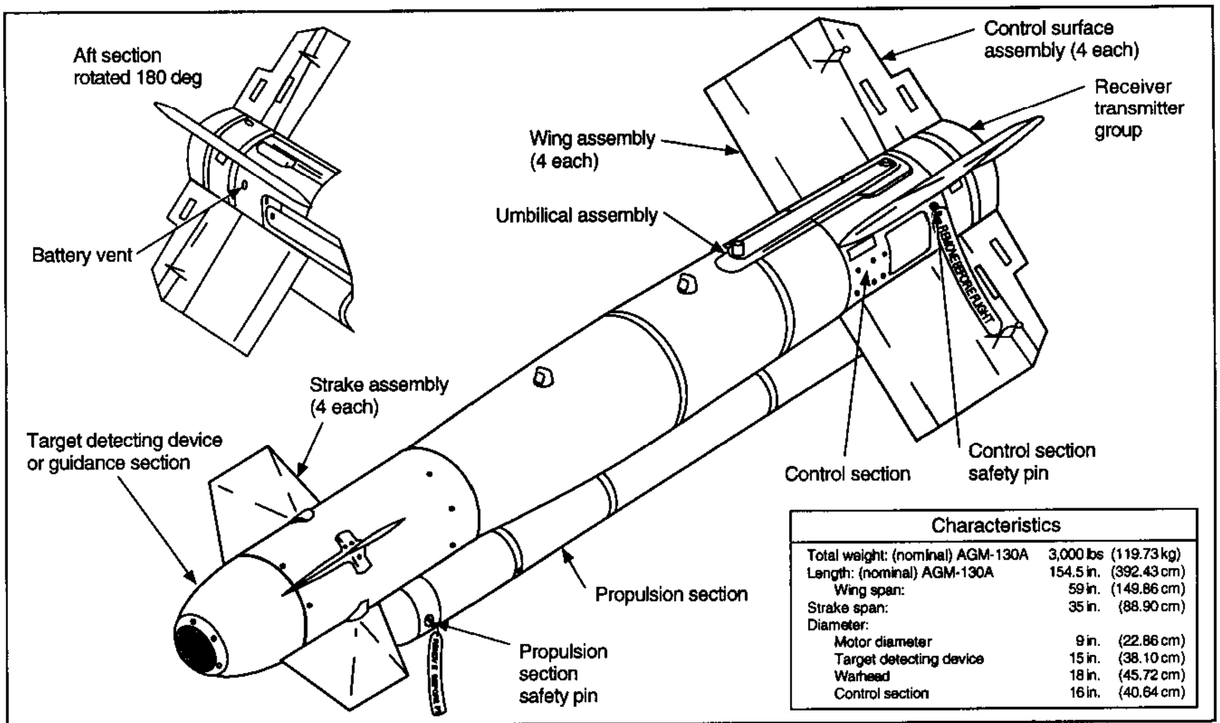
1. INTRODUCTION
This paper describes the methods used to quantify the AGM-130/IMIRS system performance and presents the preliminary results of the production flight test on the F-111F and F-15E aircraft.

Even though today's fighter aircraft have the capability for unparalleled accuracy via direct attack, the high risk that comes with close-in delivery against well-defended targets is often unacceptable. Therefore, today's strategy is to use standoff weapons at the start of a conflict to attack key targets and draw down defenses to a point where the use of direct attack weapons becomes a viable option. In order to increase the standoff range and target detection capability of the F-111F and F-15E, the AGM-130 family of weapons needed a new IR seeker that allowed for target detection from a greater distance and had the advantages of commonality between weapon bodies, better reliability and maintainability, and lower cost. With the better resolution of a new seeker came the opportunity to extend the range of the GBU-15 weapon.

At the request of the USAF Air Combat Command, the 40th Flight Test Squadron of the 46th Test Wing in conjunction with the AGM-130 System Program Office at Eglin AFB, Florida, began conducting flight tests in 1994 to evaluate the AGM-130/IMIRS system compatibility with the F-111F and F-15E.

2. SCOPE AND METHODS OF APPROACH
To meet the requirements for a standoff, precision-guided munition with an improved IR seeker, Rockwell International Corporation developed the AGM-130A/IMIRS system. The AGM-130A (Figure 1) is a modular, precision-guided, air-to-surface munition (MK-84 bomb body) equipped with a rocket motor, wings, and control surfaces to extend the standoff range of this man-in-the-loop system. The guidance section was equipped with the WGU-42/B improved modular IR seeker, which is intended to augment the WGU-33 IR seeker for the AGM-130. IMIRS is an Argon-cooled, midwave IR focal plane array. The system autonomously images the target scene over a span of scene temperatures through passively athermalized optics.

Paper presented at the AGARD FVP Symposium on "Advances in Flight Testing", held in Lisbon, Portugal, 23-26 September 1996, and published in CP-593.



Characteristics		
Total weight: (nominal) AGM-130A	3,000 lbs	(119.73 kg)
Length: (nominal) AGM-130A	154.5 in.	(392.43 cm)
Wing span:	59 in.	(149.86 cm)
Strake span:	35 in.	(88.90 cm)
Diameter:		
Motor diameter	9 in.	(22.86 cm)
Target detecting device	15 in.	(38.10 cm)
Warhead	18 in.	(45.72 cm)
Control section	16 in.	(40.64 cm)

Figure 1. AGM-130A

IMIRS provides the WSO with a missile's eye view of the target area on a cockpit display by using the datalink pod on the aircraft to receive video of the target scene transmitted by the weapon. The AGM-130/IMIRS is controlled by the WSO through the same datalink pod on the aircraft used to receive the weapon video. To quantify the performance of this new weapon system, a comprehensive test plan was developed that consisted of the following:

a. function/EMI/EMC tests
b. ground minimum resolvable temperature differential (MRTD) mission
c. operationally representative targets acquisition missions
d. seeker resolution missions
e. maximum range/communication performance mission
f. one live-launch mission
g. countermeasures missions (not covered here).

The ground EMI/EMC and MRTD missions, the in-flight seeker resolution missions, the operationally representative target acquisition missions, and the countermeasures missions were the prerequisites leading up to the live launch mission and successful completion of this test program.

In developing and completing this test, the test engineer drew on the vast EMI/EMC experience of the Air Force SEEK EAGLE Office, the engineering expertise of the personnel at the Guided Weapons Evaluation Facility (GWEF), the extensive and varied land ranges with tactical targets (724 square miles [mi] or 1,875 square kilometers [km]), the vast water ranges (134,000 square mi or 347,000 square km), and the one-of-a-kind instrumented test aircraft all at Eglin AFB, Florida.

3. FUNCTION/EMI/EMC TESTING

3.1 Method

The function and EMI/EMC tests were conducted to verify the AGM-130 with the IMIRS seeker met the compatibility requirements of the safety-of-flight checklist (i.e., the weapon did not interfere with the safety-of-flight systems on the aircraft and the aircraft did not interfere with the operation of the weapon). The compatibility checks were performed on the preproduction and production versions of the AGM-130/IMIRS.

The AGM-130 aircraft system checks were performed both with engines off and with engines running. The aircraft communication, radar, datalink, fuel, navigation, flight control, engine, and video display systems were checked with the weapon operating. The signal environment was monitored by personnel in the frequency control and analysis van.

3.2 Results

No anomalies relating to EMI/EMC were found on any of the aircraft.

4. GROUND MRTD MISSION

4.1 Method

IMIRS Seeker MRTD Measurements. The GWEF, with the assistance of contractor personnel, characterized the MRTD for the AGM-130/IMIRS system in the wide field of view (FOV) through the AXQ-14 datalink pod. This measurement was done both electronically (in the lab) and with a WSO in the aircraft observing the weapon system monitor for minimum resolution of the target patterns. The aircraft engines were not running, but aircraft power to the weapon system, the datalink pod, and the weapon system monitor in the aircraft was utilized for this test. The WSO viewed a target, and the delta temperature was increased until he noted recognition of the four-bar pattern. A smaller target was then put in the FOV and when thermal stability was achieved, the delta temperature was raised again.

IMIRS Noise Equivalent Temperature Differential (NETD) Measurements. The IMIRS was mounted statically in the entrance aperture of a 12-inch (in.) (0.3048-meter [m]) diameter, 60-in. (1.5240-m) focal length off-axis parabola collimator. The seeker, focused at infinity, was aligned to the differential temperature target source at the focal point of the collimator. The seeker's direct video signal was obtained before the datalink from an umbilical breakout connector with the seeker in direct attack mode (not through the datalink). The seeker was connected to test support equipment for power and control of the seeker's modes and settings. This measurement was made at the seeker video output of the sensor.

4.2 Results

The IMIRS seeker was found to have satisfactory MRTD and NETD performance. Actual performance data is classified.

5. TARGET ACQUISITION MISSIONS

5.1 Method

The F-111F and F-15E were flown against tactical (on- and off-range) targets with the AXQ-14 pod. The missions were conducted against on-range targets on the Eglin test range, such as an aircraft shelter, a headquarters building, a simulated surface-to-air missile (SAM) site, and a simulated command and control bunker. One off-range target consisted of a four-lane bridge, nuclear and conventional power plants, and a radio tower. An off-range mission with targets in a snowy background was flown on a low-level route in Nebraska. Targets consisted of bridges, a dam, buildings, and a highway intersection/overpass.

All target acquisition passes simulated a "pickle" of the weapon at approximately 14.5 nautical miles (nmi) (26.9 km) from the target, 420 knots calibrated airspeed (778 kilometers per hour [km/h]), and 1,000 feet (ft) (304.8 m) above ground level (AGL). The WSO called when commencing the run (simulating pickle), and initially the pilot flew straight and level. The WSO searched for the target, giving course corrections to the pilot as required. The WSO called when the target area was detected, when the target was recognized, and when the target aimpoint was identified. The aircraft profile can be found in Figure 2. The WSOs made their calls based on the following criteria:

- *Target detection:* When the WSO could see the target area
- *Target recognition:* When the WSO could distinguish the target building amongst a group of buildings
- *Target identification:* When the WSO could distinguish the DMPI.

5.2 Results

The rating of the targets (from best recognition, identification, and DMPI lock ranges to worst ranges, respectively) is as follows: aircraft shelter; simulated command, control, and communication (C^3) bunker; headquarters building; and the simulated SAM site. The simulated SAM site was probably the most difficult because it was obscured by trees until late in the weapon profile. The aircraft shelter was the easiest to break out because it was a concrete target against a grass and tree background. From the data, it appears that there was no significant difference between the day and night capability of the seeker against these targets with the exception of the aircraft shelter. The recognition, identification, and DMPI lock ranges were consistently and significantly higher for the aircraft shelter with the DMPI lock ranges having the largest disparity on average. For the most part, and ignoring the target lock ranges for the reasons previously mentioned, the recognition, identification, and DMPI lock ranges increased on subsequent runs against the same target.

Tables 1 and 2 show how successful the WSOs were in using the IMIRS seeker. This seeker will allow the aircrew to launch at a larger standoff range with great confidence of being able to locate and hit the target.

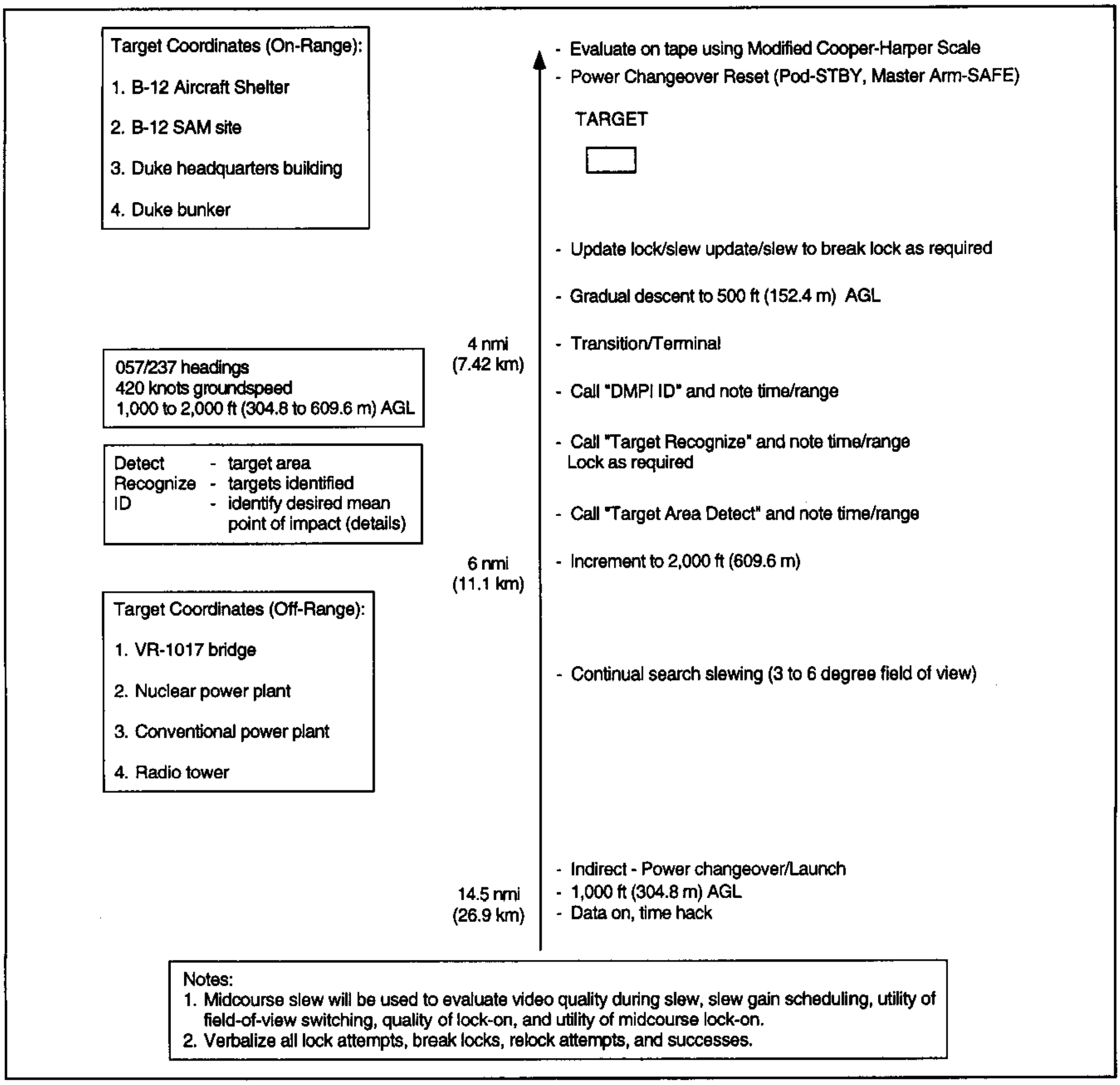


Figure 2. IMIRS On-Range and Off-Range Tactical Target Passes

Table 1. Target Acquisition for Day Missions

Target	Target Recognition	DMPI Identification	Target Lock-on	DMPI Lock-on
Headquarters	24/24	23/24	23/24	22/24
C^3 bunker	19/19	19/19	19/19	15/19
Simulated SAM site	20/20	20/20	20/20	17/20
Aircraft shelter	21/22	21/22	19/22	18/22
Percent	99	98	95	85

Table 2. Target Acquisition for Night Missions

Target	Target Recognition	DMPI Identification	Target Lock-on	DMPI Lock-on
Headquarters	8/9	6/9	4/5	3/5
C^3 bunker	9/9	9/9	7/8	6/8
Simulated SAM site	8/8	8/8	5/6	5/6
Aircraft shelter	10/10	10/10	9/9	9/9
Percent	97	92	89	82

6. RESOLUTION MISSIONS

6.1 Method

The resolution missions were flown to evaluate the spatial and thermal resolution of the IMIRS system. To meet this objective, captive missions were flown against two passive, vertical plywood targets and the active Infrared Resolution Target Set (IRRTS) (shown in Figure 3) on the Eglin range as calibrated engineering standards. The two passive targets consisted of four black painted bars on a white background. The temperature difference between the black and white bars on the passive targets was determined by the paint emissivities, solar loading, wind speed, and wind direction. Each bar on the passive targets was 28 ft (8.5344 m) long and 4 ft (1.2192 m) wide for a 7:1 aspect ratio. One passive target had vertical bars, and the other had horizontal bars. Both the active and passive targets were positioned facing south (180-degree aspect), and they had an 80-degree slope with the ground (10 degrees off the vertical). The passive targets were positioned in a uniform grass background and positioned far enough away from any other objects so that the background in wide FOV was uniform at 2 nmi (3.7 km). The majority of the resolution passes were flown in wide FOV. The active IRRTS board was configured with four vertical hotter bars and three vertical colder bars. Each bar was 2 ft (0.6096 m) wide and 14 ft (4.2672 m) long. A constant temperature difference was maintained as much as possible between the hot and cold bars on the active target. Separate passes were required for resolution tests on each target board.

The missions were flown on the F-15E in the IMIRS/weapon datalink (WDL)/AXQ-14 pod configuration. All resolution passes simulated pickle at 10 to 14.5 nmi (18.5 to 27 km) from the target, 2,000 ft (610 m) AGL, and 420 knots groundspeed (KGS) (778 km/h). The WSO called when commencing the run (simulating pickle), and the pilot flew straight and level at the target. The WSO searched for the target board and gave course corrections to the pilot as required. The WSO called when the target board was acquired (at this point, the individual bars were not resolvable). The WSO called out when he could resolve four distinct black bars. After resolving the bars, the WSO maintained the bar pattern on the target board in the FOV of the seeker.

The WSO was careful not to place the weapon crosshairs on any area of the board. The majority of the captive resolution passes were flown in wide FOV.

Prior to and immediately after each resolution pass, weather data were measured. The weather data included measurements of air temperature, humidity, barometric pressure, wind speed, wind direction, surface visibility, pyranometer, and pyrheliometer (solar loading). These measurements were required to calculate atmospheric attenuation with the LOWTRAN and MODTRAN computer models and to calibrate to target board thermal signatures. The METVAN, parked 700 ft (213 m) southwest of the Thermal Image Processing System (TIPS) van, was used to collect weather data. Ground truth images of the target board being tested were collected by an imaging radiometer operating in the same waveband as that of the IMIRS seeker immediately prior to and after each pass over the target board. Four black-body sources were provided to calibrate the imaging radiometer. The blackbody temperatures were set to near ambient and 10, 30, and 50° Celsius above ambient. The TIPS van, parked 500 ft (152 m) south of the engineering targets, was used to collect the ground truth imagery. The average apparent temperatures for each bar on the targets were calculated from the TIPS imagery and used in later analysis. The Eglin FPS-16 radar system was used to track the target aircraft.

The weather conditions were assessed 2 hours prior to takeoff for the captive resolution tests. The weather minimums for conducting this test were a 5,000-ft (1524-m) cloud deck and 7 nmi (13 km) visibility. Since two of the resolution targets were passive, they used sunlight to heat up the different color paints enough to get a sufficient temperature differential.

6.2 Results

It was found that black hot was better for target detection, but white hot was better for identifying four distinct bars. In almost all cases, the bars on Target 3 (passive, horizontal bars) were the first to break out for identification. The active IRRTS board heated the colder bars to approximately 2° Celsius above ambient to provide more control over the colder bars.

Weapon video from the resolution tests were analyzed to determine the time at which the WSO identified the four hot bars on the engineering targets. Also, three analysts reviewed the same imagery to determine the time at which they could identify the four hot bars when viewing the tape on a video monitor in a laboratory environment. The target identification times were used to calculate the target identification ranges from the time-tagged target range time-space-position information (TSPI) data.

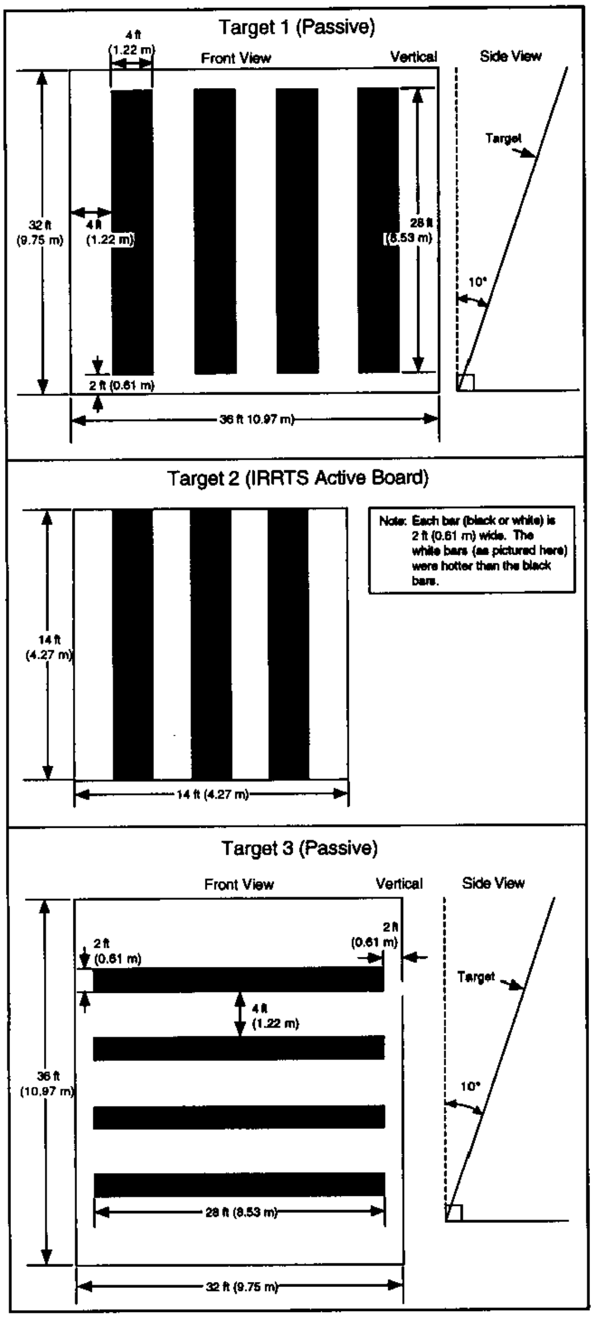


Figure 3. IMIRS Resolution

The 14 passes against the passive targets flown in wide FOV and white hot were analyzed to determine if a relationship existed between target identification range and the target bar temperature differentials (delta T) measured by the TIPS imaging radiometer. A plot of range versus delta T shows that no strong relationship exists between increased delta T and increased identification range. Therefore, range performance was limited by the spatial resolution of the seeker significantly more than it was limited by the target contrast. Consequently, the thermal resolution of the IMIRS seeker was not reached during the captive-carry resolution tests. However, the IMIRS thermal resolution was tested during the MRTD tests conducted with the seeker operating in a hangar.

7. MAXIMUM RANGE/COMMUNICATION PERFORMANCE MISSION

7.1 Method

This portion of the test was flown to assess the communications performance of the system by looking at multipath, signal-to-noise ratio, datalink, and range effects. This mission had an F-111F carrying an instrumented mock-up vehicle (IMV)/ IMIRS/WDL, and an F-15E configured with an AXQ-14 pod. These test missions were performed following two-ship standoff attack profiles with the F-111F serving as the delivery or truck aircraft and the F-15E serving as the standoff controller aircraft on each pass. The F-15E flew in the same heading as the F-111F in a loose-line abreast formation approximately 1/2 nmi (0.926 km) apart at range.

The F-111F simulated an attack of a land target (the simulated headquarters building on Test Area B-12) while the F-15E stood off over the Gulf of Mexico. The target was a large building that was two stories high (with a small cupola on top of it). The F-111F simulated a launch at approximately 14.5 nmi (27 km) from the target while at 1,000 to 2,000 ft (305 to 610 m) at 450 KGS (834 km/h). The F-111F would simulate the weapon going Transition/Terminal at approximately 4 nmi (7.4 km) from the target with a gradual descent to 300 ft (91 m) AGL.

The F-15E stood off at approximately 25,000 to 31,000 ft (7,620 to 9,449 m) AGL and initially at a base distance from the F-111F. The separation distance between the F-111F and the F-15E was controlled from the Centralized Control Facility (CCF). The F-15E received the video signals from the F-111F and acted as the controlling aircraft on each pass. After the F-15E acted as the weapon controller at each distance, the separation between the F-111F and F-15E was increased and another set of passes was accomplished.

This process was repeated until the test engineer terminated the test when it was determined that the maximum required separation range was reached. The weather minimums set for this test were a 2,500-ft (762 m) cloud ceiling and 3 nmi (5.56 km) visibility.

7.2 Results

The seeker was operated in the EDGE/BLACK mode for runs 1 to 4 and EXP/WHITE for runs 5 to 9. After pass 4B, both aircraft switched to using EXP/WHITE to get a better video scene consistent with the target heating up during the mid-morning hours. Wide FOV was primarily utilized on all runs. The F-15E acted as the control aircraft one time at the first two distances. The F-15E acted as the control aircraft two times at the remaining three distances.

AXQ-14 Pod Results. During the initial runs, no real problems were noted; however, as the distance between the weapon and pod was increased, there were more frequent command link dropouts. On one run, the conditions may have been significant enough that accurate weapon delivery may not have been possible. Similar multipath related video fades were experienced at extended separation ranges. On two runs, the laser fire button did not command Terminal as expected after Transition was selected. This may have been caused by the extreme ranges at which the aircrew was operating.

Actual separation distances, recognition and identification ranges, and additional comments are classified.

8. LIVE-LAUNCH MISSION

8.1 Method

After the satisfactory dress rehearsal missions, one live-launch mission was performed. A target designation/identification pass, IMV passes, and three other types of passes (alpha, bravo, and charlie) were executed against the launch target. On the downwind leg of one pass, various weapon functions were checked with telemetry (TM). On the alpha pass, radio confirmation was made between the aircrew and the test engineer in the CCF, and the aircrews practiced the timing and aircraft spacing. On the bravo pass, a power changeover was accomplished (the weapon used power from the weapon batteries, not from the aircraft), and a practice pass over the target was performed. The target was a 32- by 40-ft (9.75- by 12.2-m) painted billboard type target with alternating black and white squares that decrease in size. (See Figure 4 for a diagram of the launch target.) The safety engineer conducted a TM check of the flight termination system (FTS) destruct signal and directed the range controller to ensure no personnel were within the weapon flight profile. The radar TSPI trackers and cinetheodolites performed system checks on the alpha and bravo passes and recorded data on the charlie pass, which was the weapon release pass. The aircraft controller in the CCF adjusted the standoff range based on winds and vectored the aircraft into the run-in heading. The aircrew launched the weapon and performed an egress maneuver by turning right. The high-speed cameras began filming when the weapon was approximately 200 ft (61 m) from the target. The WSO selected Transition, Terminal and locked-on to the target for automatic track.

The live-launch was performed using single-ship tactics. In single-ship tactics, the aircraft carrying the weapon performed an egress maneuver to the right from the run-in heading after releasing the weapon.

Planned AGM-130A/IMIRS launch conditions were as follows:

Airspeed - 480 knots true airspeed (890 km/h)
Altitude - 2,000 ft (610 m) AGL
Launch range - 13.5 nmi (25 km)
Cruise altitude - 2,000 ft (610 m) AGL

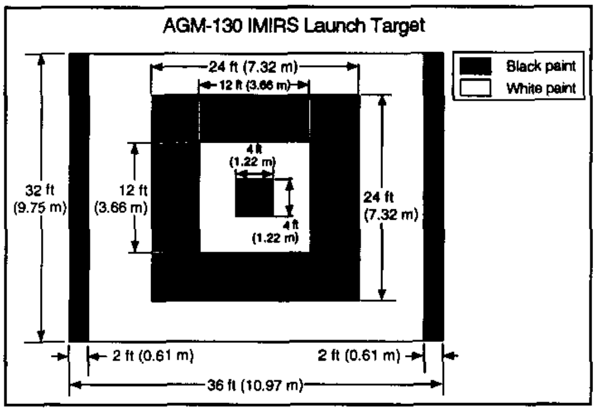


Figure 4. AGM-130 IMIRS Launch Target

If the weapon failed to respond to datalink commands after launch, a "dead-eye" radio call was to be made. If command link could not be re-established, the safety engineer planned to utilize the FTS by making a "destruct, destruct, destruct" radio call when the weapon was clear of the manned test sites. The chase aircraft was to immediately egress the area and then call "chase clear" before the destruct command was sent.

A safety footprint was established in case of a ballistic failure (control surfaces malfunctioned and vectored the weapon into the ground immediately after launch) and no motor ignition. In the event of no rocket motor ignition, a crew was available at Test Area B-70 to find the remains of the weapon after ground impact and to safe or detonate the weapon fuze in the event it did not function. After a successful target impact, Explosive Ordnance Disposal crews verified fuze function and declared the remains of the weapon safe from any further explosive detonations.

A postmission debriefing was conducted after the live launch. The WSO debriefed the test team with the videotape recording, and a preliminary assessment of the success of the target impact was made.

8.2 Results

The aircraft controller in the CCF adjusted the standoff range based on a tail wind and vectored the aircraft into the run-in heading. The run-in heading was chosen to be 235 degrees—2 degrees off the centerline of Test Area B-70. The aircrew launched the weapon and performed an egress maneuver by turning right (335-degree heading). The high-speed cameras began filming when the weapon was approximately 200 ft (61 m) from the target. The WSO selected Transition, Terminal and locked-on to the target for automatic track.

The WSO locked the seeker onto the DMPI and performed several aimpoint updates as he got closer to the target. Otherwise, the WSO remained hands-off to allow the seeker to track the target automatically. Using this method, the weapon was able to successful track the target automatically. This mission was the culmination of all previous IMIRS ground and captive-carry missions.

6. REFERENCES AND ACKOWLEDGMENTS

For reference materials and acknowledgments, please contact your AGARD liaison.