

USAF Weapon System Evaluation Program

February 1999

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**Task Report – Naval Research Laboratory
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USAF WEAPON SYSTEM EVALUATION PROGRAM

During this task period, Schafer Corporation provided engineering services and analysis to the USAF at Eglin AFB, Florida in direct support of the USAF Air-to-Surface Weapon System Evaluation Program (WSEP). Support was funded through and provided to the 86th Fighter Weapons Squadron, Eglin AFB, Florida and the Maverick Missile System Program Office (OO-ALC/LIWGM), Hill AFB, UT. The primary focus of Schafer's activities involved providing detailed engineering support for the AGM-65 Maverick Missile system in the areas of pre-flight missile build-up analysis, live launch support and post-flight data analysis and reporting.

The AGM-65 Maverick Missile is an air-launched, powered precision guided originally designed to destroy armored. Introduced in 1973, the AGM-65 has undergone significant technology and software updates over the last twenty-five years. Current variants of the AGM-65 employ electro-optical, laser or imaging infrared seekers and have either a 125 pound shaped charged warhead for armor type targets or a 300 pound blast fragmentation warhead for large targets. Developmental versions of the AGM-65 include a new CCD type seeker with modified software. Approximately 20,000 AGM-65 Maverick Missiles remain in the operational inventory.

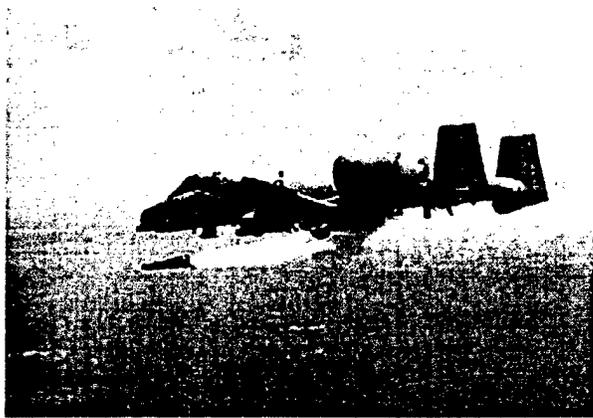
The AGM-65 Maverick Missile comprises a significant portion of the USAF precision guided munitions inventory. The USAF evaluates the operational and system performance of the weapon system each year during testing conducted by operational units under the umbrella of the USAF Weapon System Evaluation Program. Testing is conducted on instrumented test ranges at Eglin AFB, Florida and Hill AFB, Utah. Missiles are selected from operational resources and then modified with a data telemetry package, which provides missile seeker video as well as missile performance data for post flight analysis. During this task period, Schafer personnel analyzed a total of 86 missiles launched during five separate WSEP exercises. Fifty-two of these missiles were the AGM-65D variant and 24 missiles were AGM-65G's.

A key activity associated with Schafer's post flight data analysis during this task period was the identification of a critical deficiency in the missile target tracking software for the AGM-65G Maverick missile. During the last five years, over fifteen percent of the AGM-65G's launched at small tank size targets have overflowed their intended target. Schafer analysis of past and current missile seeker imagery as well as missile performance telemetry data indicated that the most likely cause of the overflight problem was a deficiency in the target tracking software. Further analysis isolated the problem to the inability of the target tracking gates to grow at a rate that matched the rate at which the target grew in the seeker imagery. The result of this tracking gate growth problem was manifested in the missile computing an erroneous target centroid location and subsequently overflying the target. Schafer efforts have lead to the modification of the missile software by the contractor. Flight testing of this modified software is planned for February and May 1999.

Final technical reports detailing the results of the post flight analysis for all AGM-65 Maverick Missiles evaluated during this task period are contained in Appendices A: Maverick Missile Launch Analysis WSEP 98-02, B: Maverick Missile Launch Analysis WSEP 98-03 and WSEP 98-06, and C: Maverick Missile Launch Analysis WSEP 98-10 and WSEP 98-11.

Schafer

COMBAT HAMMER
WEAPON SYSTEM EVALUATION
PROGRAM
MAVERICK MISSILE LAUNCH ANALYSIS
WSEP 98-02



Prepared for:

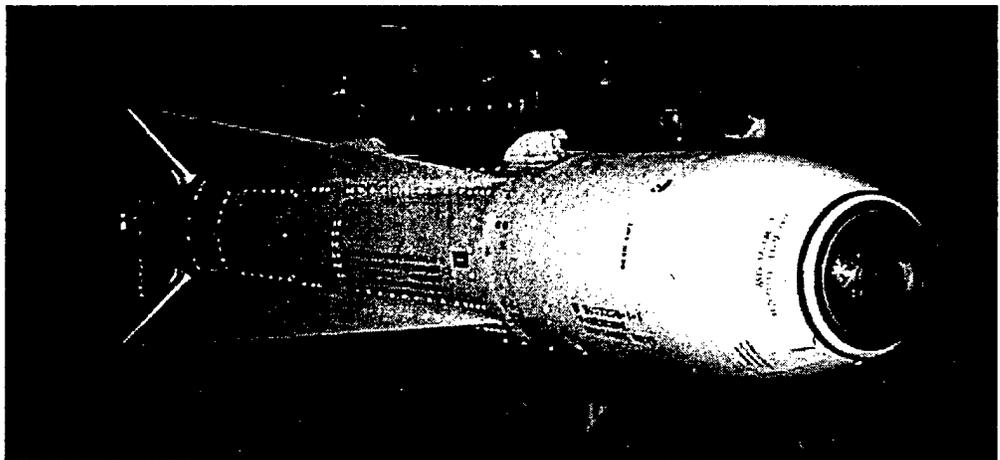
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FOREWORD

Schafer Corporation, under contract to the Naval Research Laboratory, is pleased to submit this technical report, Maverick Missile Launch Analysis, WSEP 98-02, to the 86th Fighter Weapons Squadron (53rd Wing), Air Combat Command, Eglin Air Force Base, Florida and the Maverick Missile System Program Office (OO-ALC/LIWGM), Hill Air Force Base, Utah.

This report was prepared by Mr. Sam Matthews, Senior Systems Engineer, and Mr. Steve Madley, Senior Program Manger, at Schafer Corporation's Ft. Walton Beach, Florida facility.

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1.0 EXECUTIVE SUMMARY

The 86th Fighter Weapons Squadron (53rd Wing/Air Combat Command) conducted an evaluation of the AGM-65 Maverick Missile System under the auspices of the USAF Air-to-Ground Weapon System Evaluation Program (WSEP 98-02) from 9-13 February 1998 at Eglin AFB, Florida. A-10 aircraft, aircrews and maintenance personnel from the 190th Fighter Squadron (124th Fighter Wing/Idaho Air National Guard) deployed from Gowen Field, Boise, Idaho to Eglin AFB to participate in this WSEP. Thirteen AGM-65B Maverick missiles and six AGM-65G Maverick missiles were employed during the evaluation period. Eleven of the AGM-65B Maverick missiles were successfully launched against tank type targets resulting in eleven hits. Two AGM-65B Maverick missiles failed to launch from the aircraft when the weapons release button ("pickle button") was depressed.

Three AGM-65G Maverick missiles were launched against large targets (simulated buildings) resulting in three hits. Two AGM-65G Maverick missiles were launched against tank type targets using the point track (centroid track) mode. One AGM-65G Maverick missile was launched against an incorrect target. All three missiles failed to hit the selected targets and exhibited a common "overflight" failure behavior. An analysis of the three AGM-65G Maverick missile overflight failures is contained in section 3 of this report.

Section 4 of this report discusses the AGM-65G overflight problem and suggests that the root cause of the problem is inadequate missile target tracking gate growth rates. An analysis of data indicates that over fifteen percent of the AGM-65G Maverick missiles launched at WSEP since 1993 have overflowed the intended target (14 overflights for 90 launches).

2.0 LAUNCH SUMMARY

Table 2.0.1 provides a summary of the missile launch parameters and results for WSEP 98-02.

WSEP 98-02 LAUNCH SUMMARY

WSE P DAY	WSEP Callsign	Missile Type	Missile SN	Target Type	Launch Altitude (ft AGL)	Launch Slant Range (ft)	Result	Remarks
1	Hammer 11	AGM-65B	GB03605	tank	N/A	N/A	No launch	
1	Hammer 12	AGM-65B	GB00915	tank	980	5675	Hit	
1	Hammer 13	AGM-65B	GB00403	tank	1457	8032	Hit	
1	Hammer 21	AGM-65B	GB01744	tank	1200	6074	Hit	
1	Hammer 22	AGM-65B	GB02206	tank	900	6202	Hit	
1	Hammer 23	AGM-65B	GB00939	tank	900	6202	Hit	
2	Hammer 11	AGM-65G	GG01608	building	873	8793	Hit	
2	Hammer 12	AGM-65G	GG01791	building	920	9402	Hit	
2	Hammer 13	AGM-65G	GG01790	building	850	8972	Hit	
2	Hammer 21	AGM-65G	GG02971	fire ¹	700	6358	Miss	Overflight
2	Hammer 22	AGM-65G	GG04248	tank	1310	8607	Miss	Overflight
2	Hammer 23	AGM-65G	GG02749	tank	1019	7182	Miss	Overflight
3	Hammer 11	AGM-65B	GB00068	tank	891	4882	Hit	
3	Hammer 12	AGM-65B	GB03542	tank	875	4879	Hit	
3	Hammer 13	AGM-65B	GB01399	tank	1000	9894	Hit	
3	Hammer 21	AGM-65B	GB03605	tank	911	7710	Hit	
3	Hammer 22	AGM-65B	GB00176	tank	960	5492	Hit	
3	Hammer 23	AGM-65B	GB01461	tank	N/A	N/A	No launch	
3	Hammer 24	AGM-65B	GB00670	tank	529	4708	Hit	

TABLE 2.0.1

¹ Missile locked onto and tracked ground fire. Track was stable throughout missile flight with missile overflying target.

Figure 2.0.1 depicts the missile launch parameters for WSEP 98-02.

WSEP 98-02 LAUNCH PARAMETERS

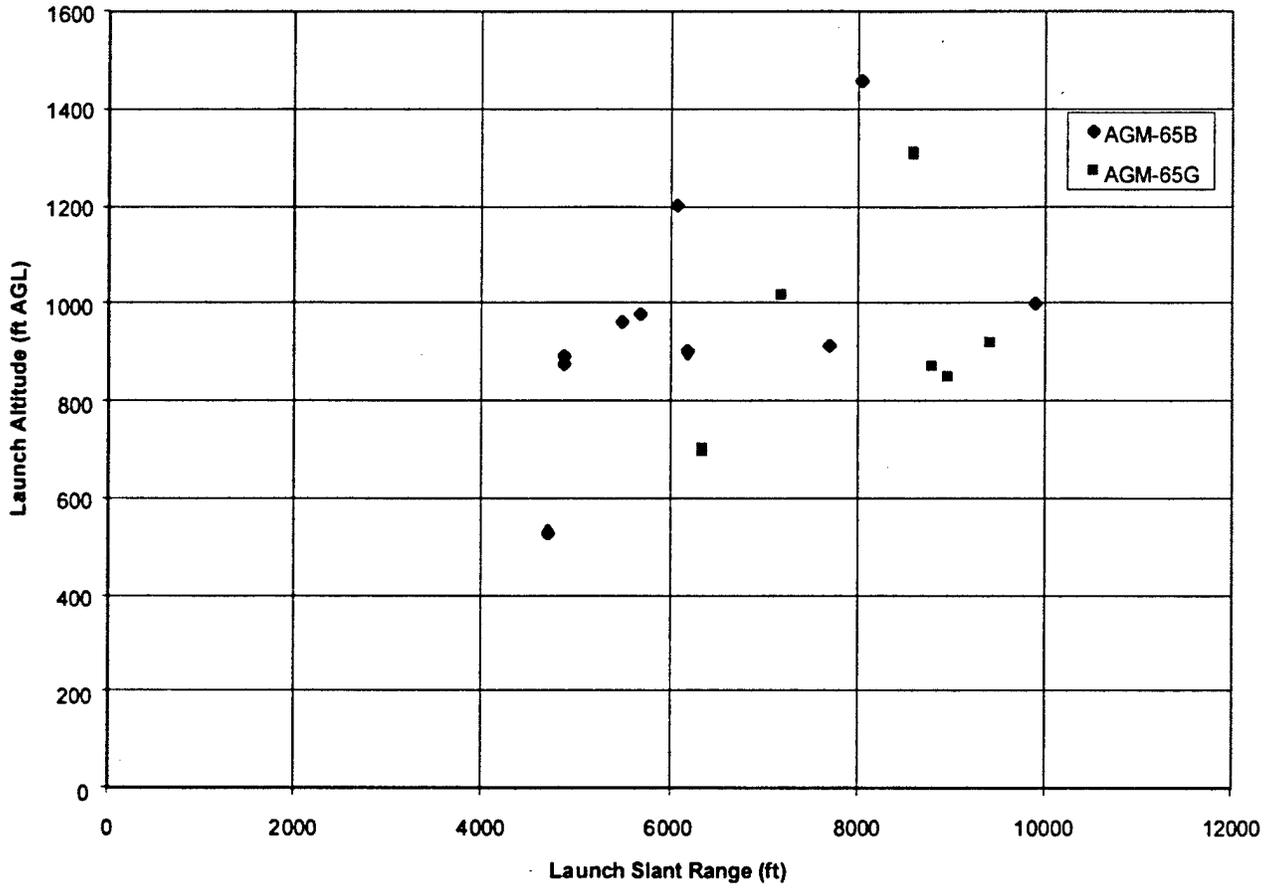


FIGURE 2.0.1

3.0 LAUNCH ANALYSIS

3.1 AGM-65B

Thirteen AGM-65B Maverick missiles were employed during this WSEP resulting in eleven hits. Two missiles failed to fire when the weapon release button ("pickle button") was depressed. Both of these missiles were returned to base for maintenance failure analysis.

It was observed that all of the AGM-65B Maverick missiles were launched at slant ranges to the target of less than 10,000 feet with six missiles being launched at slant ranges of less than 1 nautical mile (6076 feet). Nine AGM-65B Maverick missiles were launched at altitudes below 1000 feet above ground level (agl) while the remaining two missiles were launched below 1500 feet agl.

3.2 AGM-65G

Six AGM-65G Maverick missiles were employed during this WSEP resulting in three hits and three misses. All three missiles which hit their intended targets were launched against a large target (simulated building). Two of these missiles were launched in the point track (centroid track) mode and one missile was launched in the area track (correlate track) mode.

The three AGM-65G Maverick missiles which missed their intended targets (Hammer 21/Day2, Hammer 22/Day2 and Hammer 23/Day2) were all launched in the point track mode. All three missiles exhibited similar missile flyouts which resulted in the missile overflying the intended target. These missiles exhibited stable target track until just prior to impact when the intended target size growth rate exceeded the missile tracking gate growth rate. Two of the missiles (Hammer 22 and Hammer 23) were launched against valid tank targets while one missile (Hammer 21) was launched against an invalid target. This missile was launched against a ground fire which was exhibiting a stable target signature similar to a tank. The missile tracked the ground fire until

the target signature growth rate exceeded the tracking gate growth rate and the missile overflowed the target.

It was noted in all three misses that even after the actual target was no longer being gated by the missile target tracking gates, the missiles exhibited stable flight and continued to track what appeared to be erroneously computed target centroids. Figures 3.2.1, 3.2.2 and 3.2.3 below depict seeker imagery during missile overflight of the target.

HAMMER 21 OVERFLIGHT

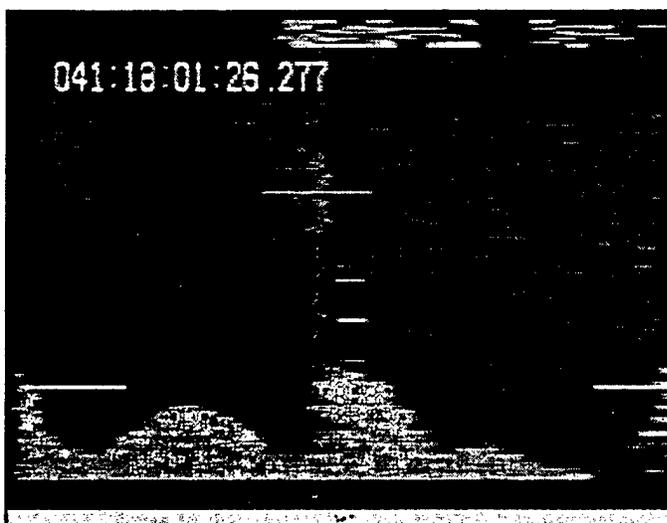


Figure 3.2.1

HAMMER 22 OVERFLIGHT

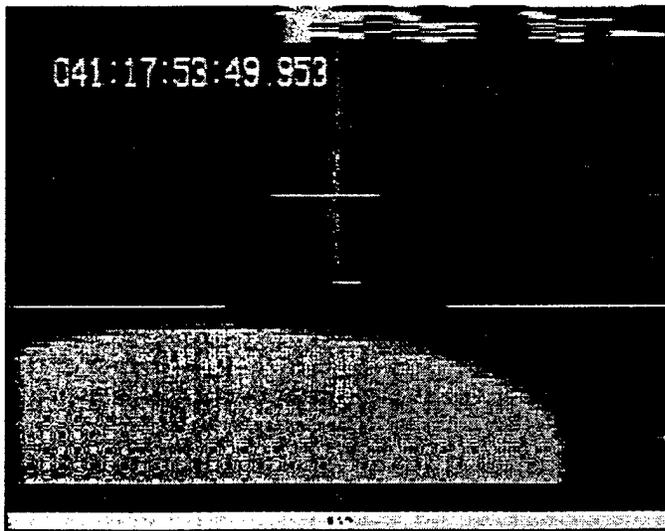


Figure 3.2.2

HAMMER 23 OVERFLIGHT

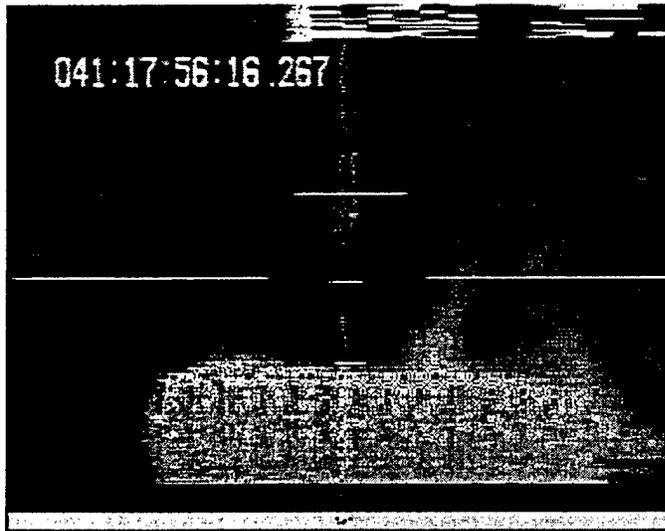


Figure 3.2.3

4.0 AGM-65G Overflight Problem

4.1 Background

Since 1993, over fifteen percent of the AGM-65G Maverick missiles launched in the point track (centroid track) against small (tank size) targets during WSEP have overflown the intended target. To date the cause of this problem has not been conclusively identified. Table 4.1.1 below summarizes AGM-65G Maverick missile launches since 1993.

AGM-65G WSEP LAUNCH SUMMARY

WSEP	Total Missiles	Hit	Miss	Overflight
93-09	13	7	4	2
94-03	1	1	0	0
94-06	9	6	1	2
94-12	5	3	1	1
95-02	16	10	6	0
95-05	15	9	4	2
96-02	7	3	3	1
96-03	3	1	1	1
96-09	7	6	1	0
97-01	2	0	1	1
97-02	0	0	0	0
97-03	4	1	2	1
97-08	2	2	0	0
97-09	3	1	2	0
98-02	3	0	0	3
<u>TOTAL</u>	90	50	26	14

TABLE 4.1.1

A total of 90 AGM-65G Maverick missiles were launched in the point track mode against small targets resulting in a hit rate of .556 and a miss rate of .446. For the purposes of this analysis, overflights are considered as a subset of misses. When considered separately, the overflight rate was .155 (14 of 90 missiles launched). This rate is considered statistically significant.

During this same period, a total of 65 AGM-65D Maverick missiles were launched resulting in a hit rate of .708 and a miss rate of .292.

Figure 4.1.1 below depicts the data contained in Table 4.1.1.

AGM-65G WSEP RESULTS

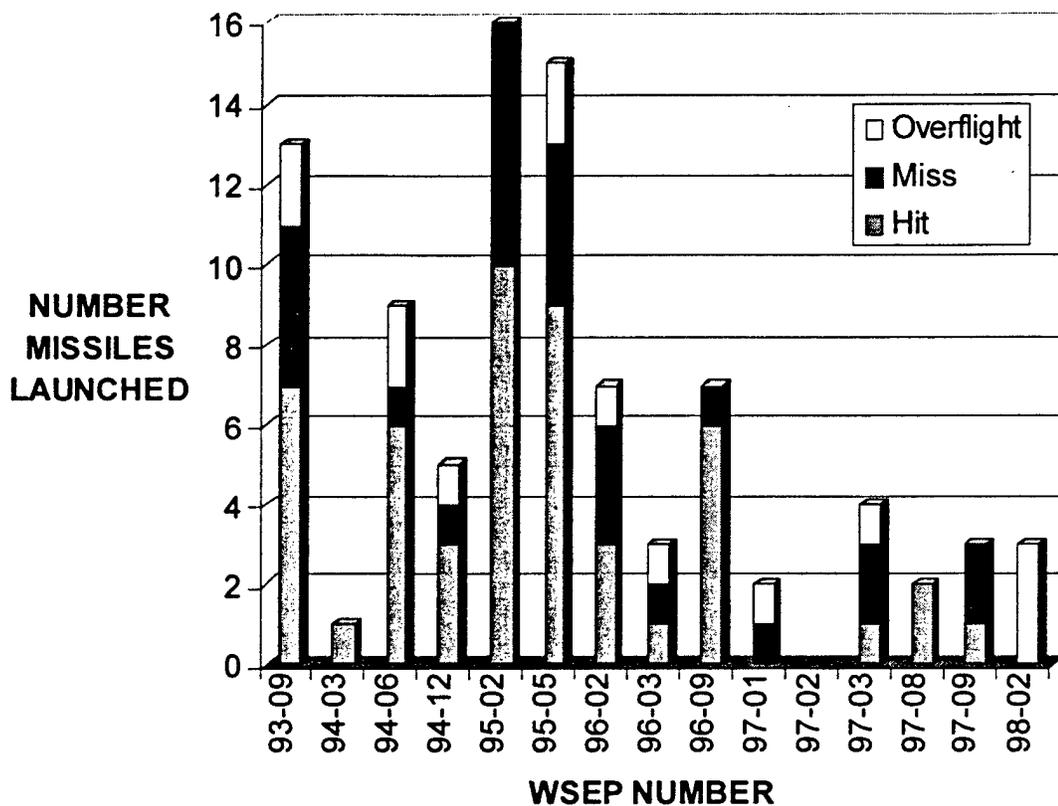


FIGURE 4.1.1

Figure 4.1.2 below depicts AGM-65D and AGM-65G hit/miss rates (where overflights are considered to be a subset of misses).

AGM-65D and AGM-65G WSEP HIT/MISS RATES
(Misses include overflights)

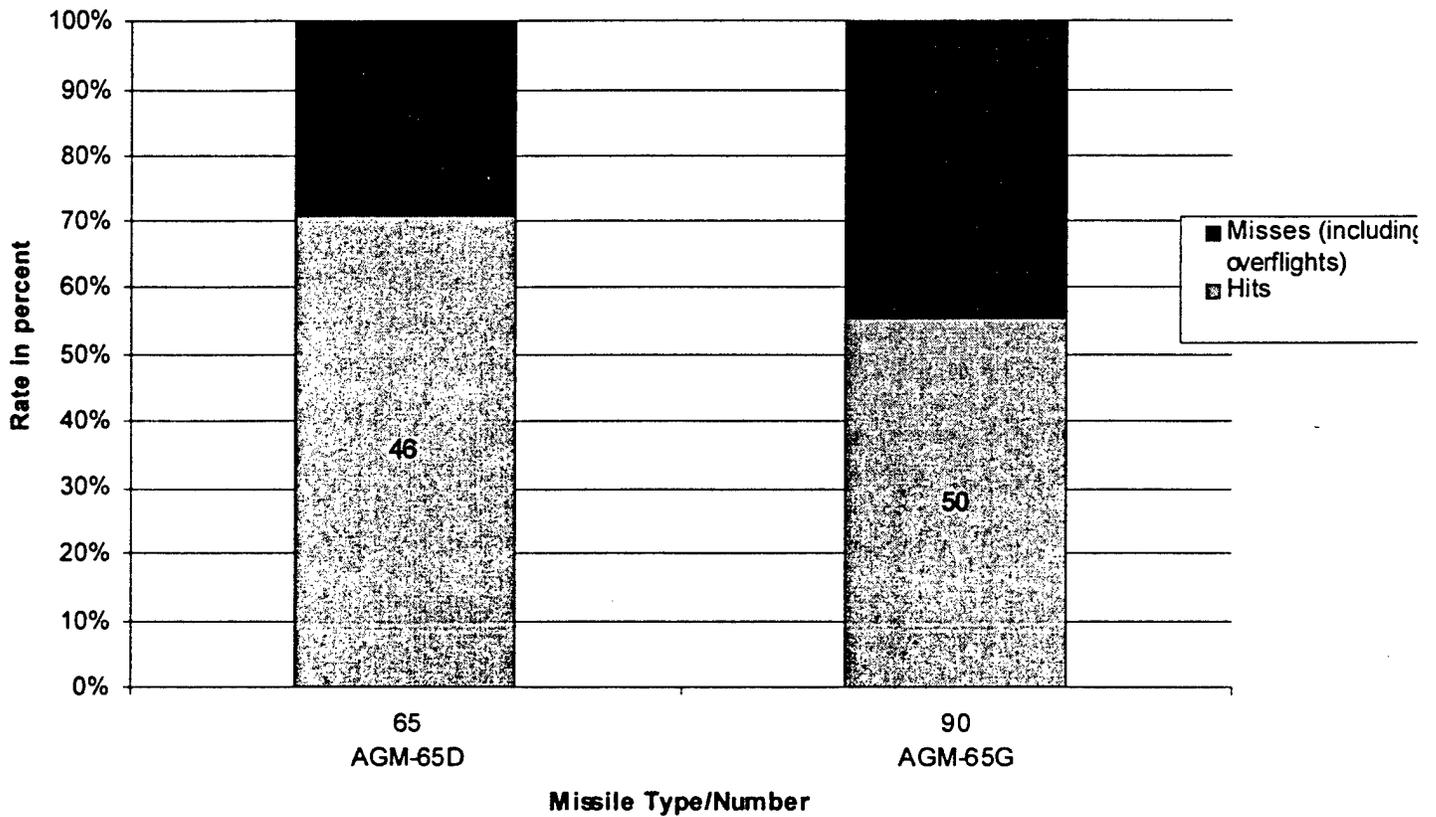


FIGURE 4.1.2

Figure 4.1.3 below depicts AGM-65D and AGM-65G hit/miss rates when all AGM-65G overflights are reclassified as hits. The assumption that AGM-65G overflights can be reclassified as hits for comparison purposes is supported by the fact that all missiles that overflew the intended target were performing properly and tracking prior to exhibiting the overflight anomaly.

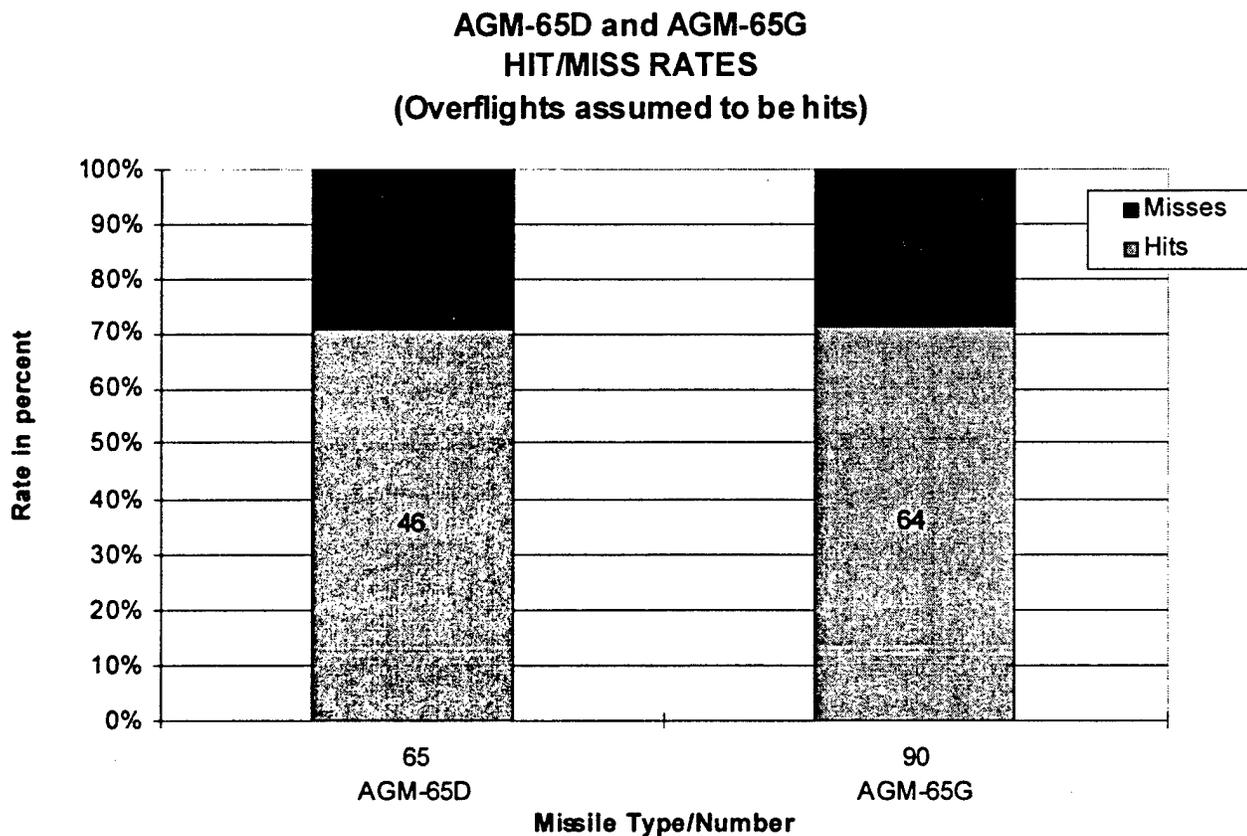


FIGURE 4.1.3

Figure 4.1.3 shows that the AGM-65D and AGM-65G hit/miss rates (AGM-65D: .708 hit / .292 miss; AGM-65G: .711 hit / .289 miss) are statistically similar when AGM-65G overflights are reclassified as hits. This data confirms that the AGM-65G overflight problem is significant and is adversely impacting the overall performance of the AGM-65G Maverick missile system.

4.2 Technical Analysis

During WSEP 98-02, three AGM-65G Maverick missiles were launched in the point track (centroid track) mode against small (tank size) targets. All three missiles initially tracked the intended target but overflowed the target in the end game. As discussed in section 3.2.2 of this report, Hammer 23 was launched against an invalid target but performed normally until end-game overflight. Analysis of missile telemetry data, missile seeker video and missile video encoded symbology indicated that all three missiles exhibited similar overflight behavior. Table 4.2.1 below summarizes the launch conditions for these three missiles.

LAUNCH SUMMARY

Missile Launch	Serial Number	Altitude (ft AGL)	Airspeed (KTAS)	Ground Range (ft)	Slant Range (ft)
Hammer 21	GG02971	700	320	6319	6358
Hammer 22	GG04248	1310	300	8506	8606
Hammer 23	GG02749	1019	326	7109	7182

TABLE 4.2.1

For the purposes of providing a general understanding of the AGM-65G overflight problem, this analysis will focus on the missile launched from Hammer 22 on Day 2 (missile serial number GG-04248). Figures 2.1.1 through 2.1.5 below are video frames for Hammer 22 telemetry data which depict various phases of the missile flyout. Missile time of flight was 7.30 seconds.

HAMMER 22, Launch +1.10 sec (6.80 sec prior to overflight)

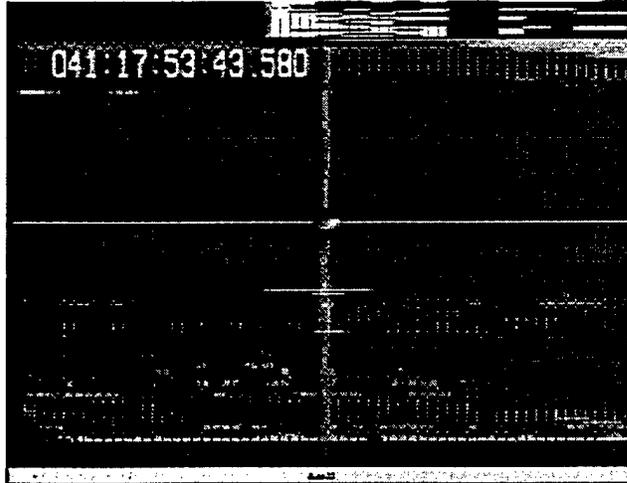


FIGURE 4.2.1

HAMMER 22, Launch +5.88 sec (1.42 sec prior to overflight)

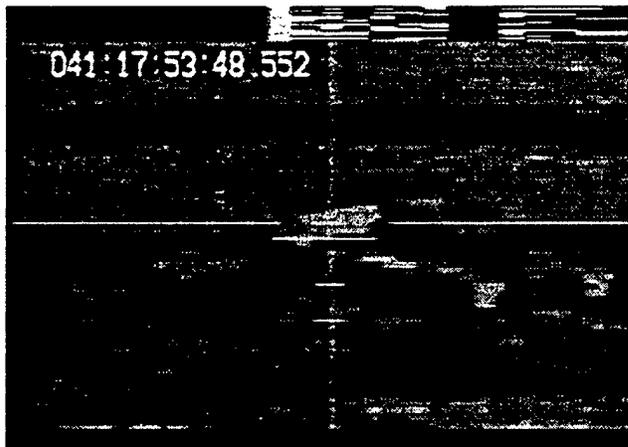


FIGURE 4.2.2

HAMMER 22, Launch +6.80 sec (0.5 sec prior to overflight)



FIGURE 4.2.3

HAMMER 22, Launch + 7.13 sec (0.17 sec prior to overflight)

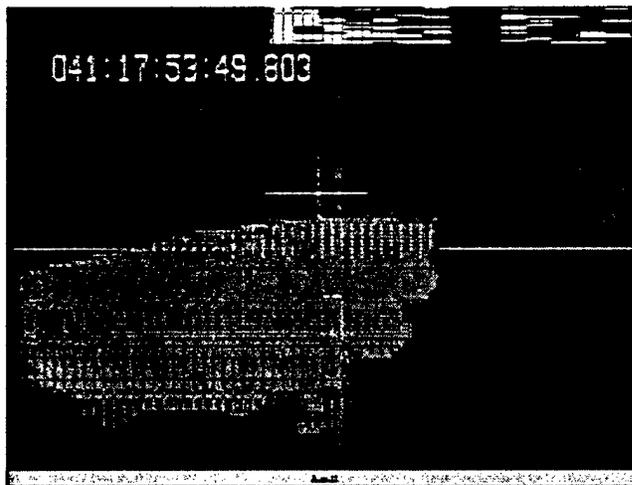


FIGURE 4.2.4

HAMMER 22, Launch +7.30 sec (target overflight)



FIGURE 4.2.5

Figure 4.2.4 clearly indicates the target tracking gate shift from the actual target centroid at approximately 0.17 seconds prior to missile overflight. Figure 4.2.5 shows missile tracking gate location at missile overflight. It was observed that the missile continued to guide to the erroneously computed target centroid and impacted the ground at the position being gated. No break-lock or missile event flags were observed while the missile was tracking the erroneous centroid.

When the missile is commanded to lock onto a target in point track mode, missile software computes an initial target centroid. This initial computation is a complex calculation that looks at each pixel and each line segment of the video frame (field in the case of the AGM-65D) and then places the tracking gates about the designated target. After the initial centroid computation, missile software then calculates a new target centroid for each video frame (30 Hz). This centroid calculation uses either the smaller of ten pixels or one-half the horizontal gate size ("X" gate) and either the smaller of ten TV lines or one-half the vertical gate size ("Y" gate) to compute changes

in the target centroid. The missile then tracks the new target centroid based upon this calculation. For large targets, the missile software typically invokes the ten pixel by ten TV line calculation while small (tank size) targets use the one-half gate size computation. In both cases, the missile tracking gates reflect the computed position of the target centroid.

Missile encoded symbology and missile video telemetry were analyzed for Hammer 22 to determine computed and actual target centroid location using target centerline positions and target tracking gate size. Figure 4.2.6 below shows the missile computed vertical target centerline and the actual target vertical centerline for Hammer 22.

Hammer 22
Computed vs Actual Target Centerline

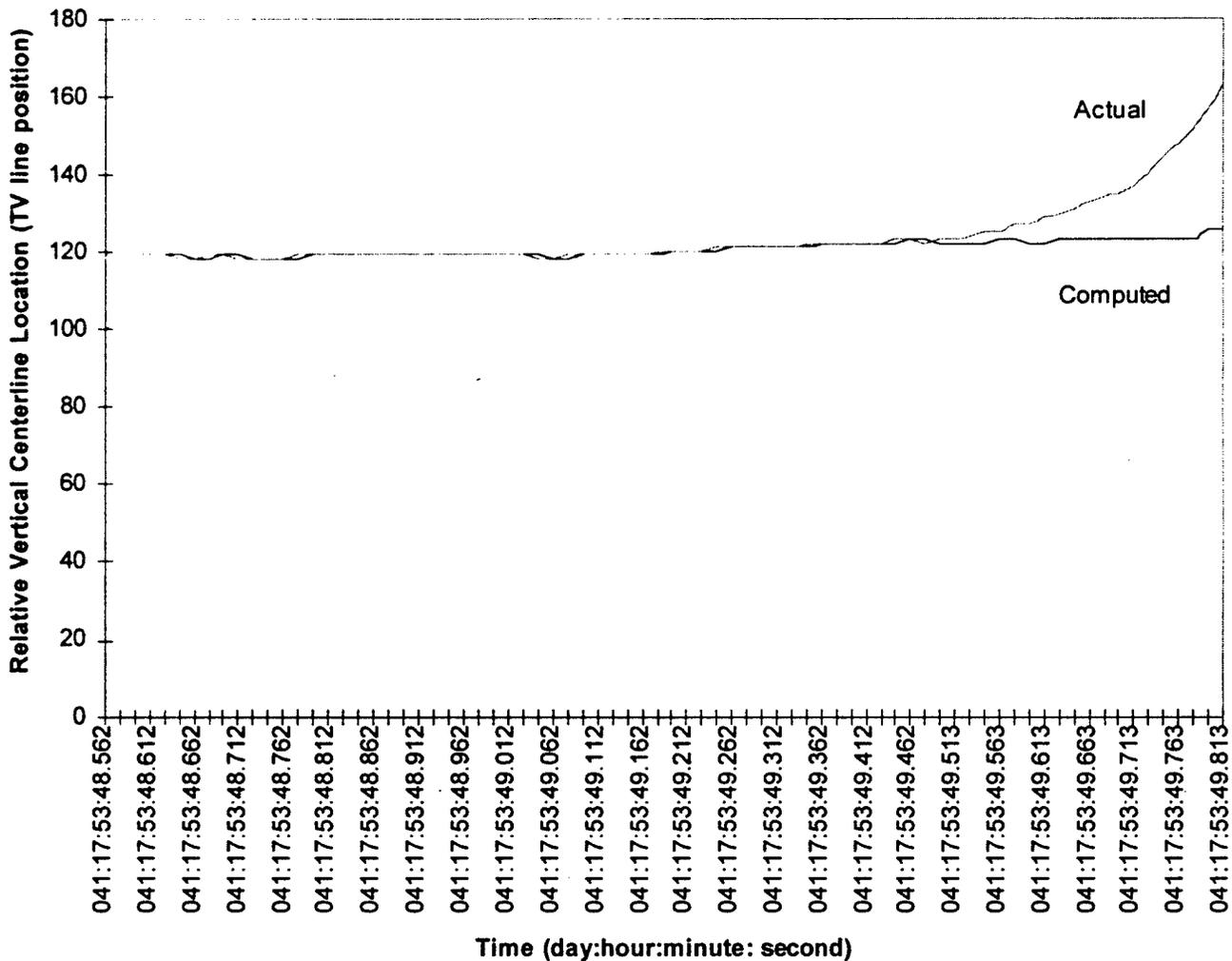


FIGURE 4.2.6

Figure 4.2.7 depicts the computed vertical gate size versus the actual gate size for Hammer 22.

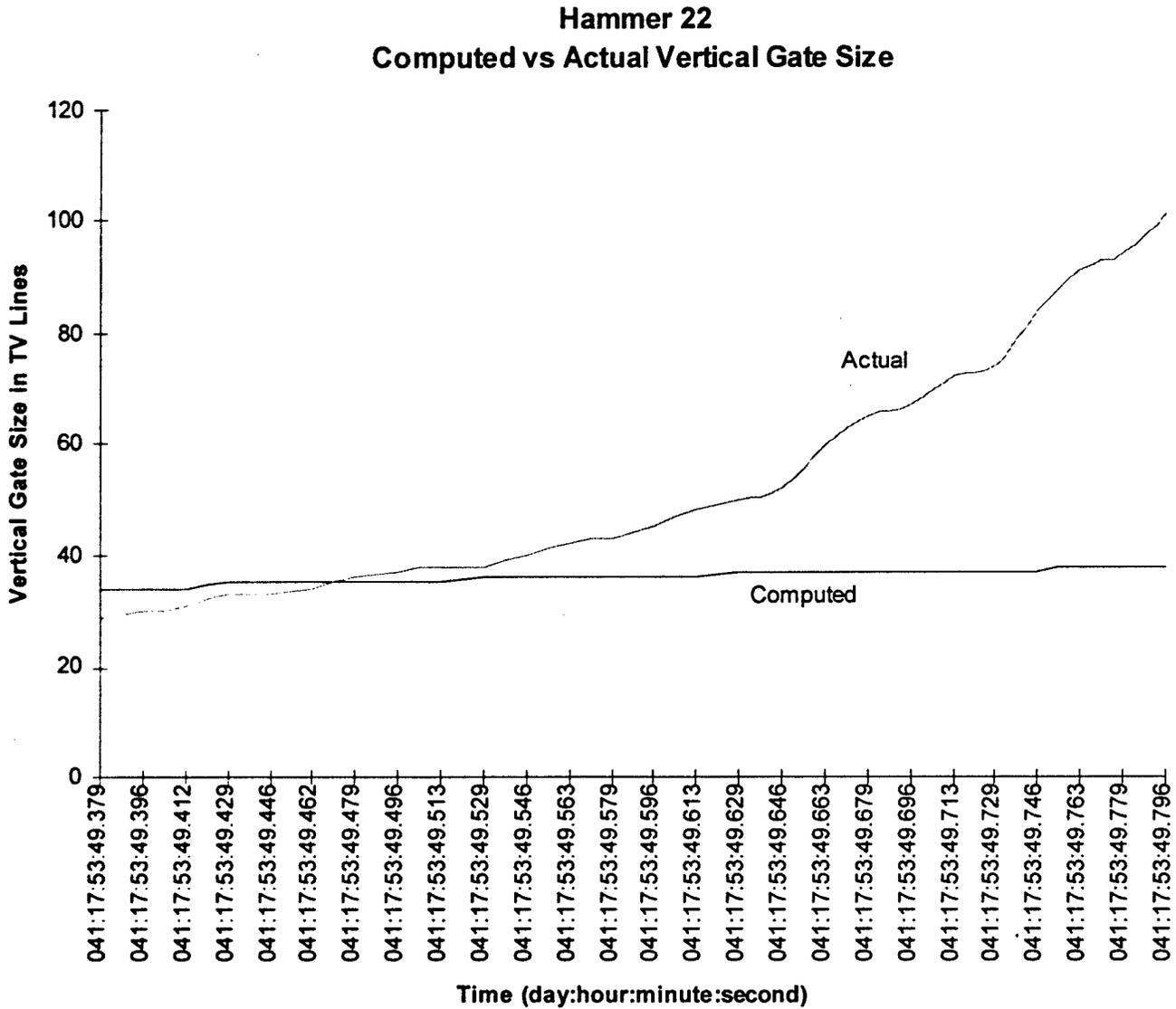


FIGURE 4.2.7

An analogous situation exists for the missile computation of the horizontal (X axis) target centerline and target tracking gate locations as well as the horizontal target tracking gate size.

It is readily apparent from Figure 4.2.7 that when the actual target size growth rate exceeds the target tracking gate growth rate, the missile will then be tracking an erroneous target centroid because the missile is improperly calculating the actual target vertical and horizontal centerlines. Testing at the Guided Weapons Evaluation Facility (GWEF) at Eglin AFB, Florida has confirmed that the AGM-65G tracking gates appear to grow at about one-third the rate at which the AGM-65D tracking gates grow for the same target. The AGM-65D and AGM-65G Computer Program Product Fabrication Specifications, however, show that the tracking growth rate equations are identical and hence the AGM-65G should exhibit target gate growth rates identical to the AGM-65D.

4.3 Conclusions

All three AGM-65G missiles launched at small (tank size) targets in the centroid mode (point track) during WSEP 98-02 exhibited similar overflight behavior. An analysis of data from Hammer 22 points to target gate growth errors which result in the missile tracking an erroneous target centroid.

Testing conducted at the Guided Weapons Evaluation Facility confirmed that the AGM-65G target tracking gates grow at about one-third the rate at which the AGM-65D target tracking gates grow for an identical target.

Analysis of data for AGM-65G launches conducted at WSEP since 1993 shows that 15.5% of all AGM-65G's launched overflowed the intended target. When AGM-65G overflights are assumed, for statistical analysis, to have hit the intended target, AGM-65D and AGM-65G hit/miss rates are nearly identical.

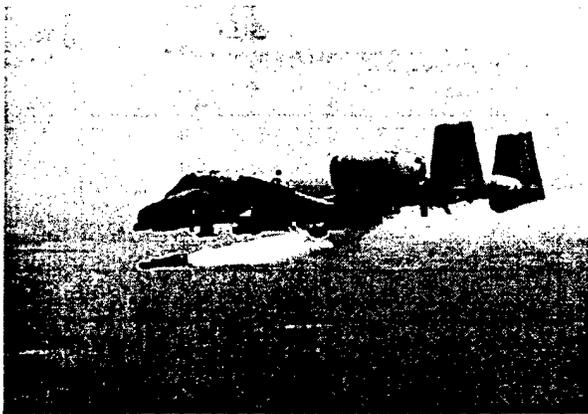
The data collected at WSEP for AGM-65G's is the most accurate measure of actual missile performance currently available and should be considered to be the most accurate indicator of overall weapon system performance. Missiles launched at WSEP are equipped with telemetry packages which provide detailed missile performance information for post flight analysis. Additionally missile impact locations are physically surveyed for precise target impact location.

Additional analysis should be accomplished to further quantify the extent of the overflight problem throughout the employment envelope of the AGM-65G. Further study to define the exact cause of the target tracking growth error should be conducted.

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**COMBAT HAMMER
WEAPON SYSTEM EVALUATION
PROGRAM**

**MAVERICK MISSILE LAUNCH ANALYSIS
WSEP 98-03 and WSEP 98-06**



Prepared for:

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July 1998

FOREWORD

Schafer Corporation, under contract to the Naval Research Laboratory, is pleased to submit this technical report, Maverick Missile Launch Analysis, WSEP 98-03 and 98-06, to the 86th Fighter Weapons Squadron (53rd Wing), Air Combat Command, Eglin Air Force Base, Florida and the Maverick Missile System Program Office (OO-ALC/LIWGM), Hill Air Force Base, Utah.

This report was prepared by Mr. Sam Matthews, Senior Systems Engineer, and Mr. Steve Madley, Senior Program Manger, at Schafer Corporation's Ft. Walton Beach, Florida facility.

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1.0 EXECUTIVE SUMMARY

The 86th Fighter Weapons Squadron (53rd Wing/Air Combat Command) conducted an evaluation of the AGM-65 Maverick Missile System as part of the USAF Air-to-Ground Weapon System Evaluation Program (WSEP) from 1-5 June 1998 at the Utah Test and Training Range (UTTR). F-16C/D aircraft, aircrews and maintenance personnel from the 55th Fighter Squadron (20th Fighter Wing) deployed from Shaw AFB, South Carolina to Hill AFB, Utah to participate in WSEP 98-03. A-10A aircraft, aircrews and maintenance personnel from the 81st Fighter Squadron (52nd Fighter Wing) deployed from Spangdahm AB, Germany to Hill AFB, Utah to participate in WSEP 98-06. Twelve AGM-65D Maverick missiles were employed by the 55th Fighter Squadron during WSEP 98-03. Three AGM-65D Maverick missiles and six AGM-65G Maverick missiles were employed by the 81st Fighter Squadron during WSEP 98-06.

Of the twelve AGM-65D Maverick missiles employed in WSEP 98-03, ten missiles hit their intended armor targets, one missile failed shortly after launch and missed the target and one missile failed prior to launch (no cockpit video). Section 3 of this report provides an analysis of the two missiles that failed.

During WSEP 98-06, three AGM-65D Maverick missiles were employed against armor targets in the centroid (point track) mode resulting in one hit, one miss and one missile launch declared non-assessable. This missile was launched against a target that was evaluated as invalid. Five AGM-65G Maverick missiles were launched against large targets (simulated buildings) using the correlate (area track) mode and one AGM-65G missile was launched against a tank target using the centroid (point track) mode. Two of the AGM-65G Maverick missiles launched in area track (large targets) were launched against incorrect targets. Of the remaining three AGM-65G Maverick missiles launched in area track mode, two overflow the intended targets and one hit slightly short of the target.

Three investigative firings of AGM-65G missiles were completed during this WSEP. All three missiles were fired at armor targets in the centroid (point track) mode from medium altitude. All

2.0 LAUNCH SUMMARY

2.1 WSEP 98-03

Table 2.1.1 provides a summary of the missile launch parameters and results for WSEP 98-03.

WSEP 98-03 LAUNCH SUMMARY

WSE P DAY	WSEP Callsign	Missile Type	Missile SN	Target Type	Launch Altitude (ft AGL)	Launch Ground Range (nm)	Result	Remarks
1	Hammer 11	AGM-65D	GD12250	tank	1,000	7,846	Hit	
1	Hammer 12	AGM-65D	GD12758	tank	2,000	12,143	Hit	
1	Hammer 13	AGM-65D	GD12265	tank	2,000	15,210	Hit	
1	Hammer 14	AGM-65D	GD09282	tank	2,000	15,210	Hit	
1	Hammer 15	AGM-65D	GD09252	tank	1,480	4,582	Hit	
1	Hammer 16	AGM-65D	GD12687	tank	1,250	18,829	Hit	
2	Hammer 11	AGM-65D	GD11412	tank	N/A	N/A	N/A	No launch.
2	Hammer 12	AGM-65D	GD09257	tank	6,780	24,896	Hit	
2	Hammer 13	AGM-65D	GD12242	tank	5,381	22,000 (e)	Hit	
2	Hammer 14	AGM-65D	GD12269	tank	4,600	19,365	Miss	
2	Hammer 16	AGM-65D	GD12245	tank	2,590	16,227	Hit	
2	Hammer 15	AGM-65D	GD08304	tank	6,450	23,874	Hit	

TABLE 2.1.1

WSEP Day 1 = 2 Jun 98

WSEP Day 2 = 4 Jun 98

(e) Estimated launch slant range

Figure 2.1.1 depicts the missile launch parameters for WSEP 98-03.

WSEP 98-03 Launch Parameters

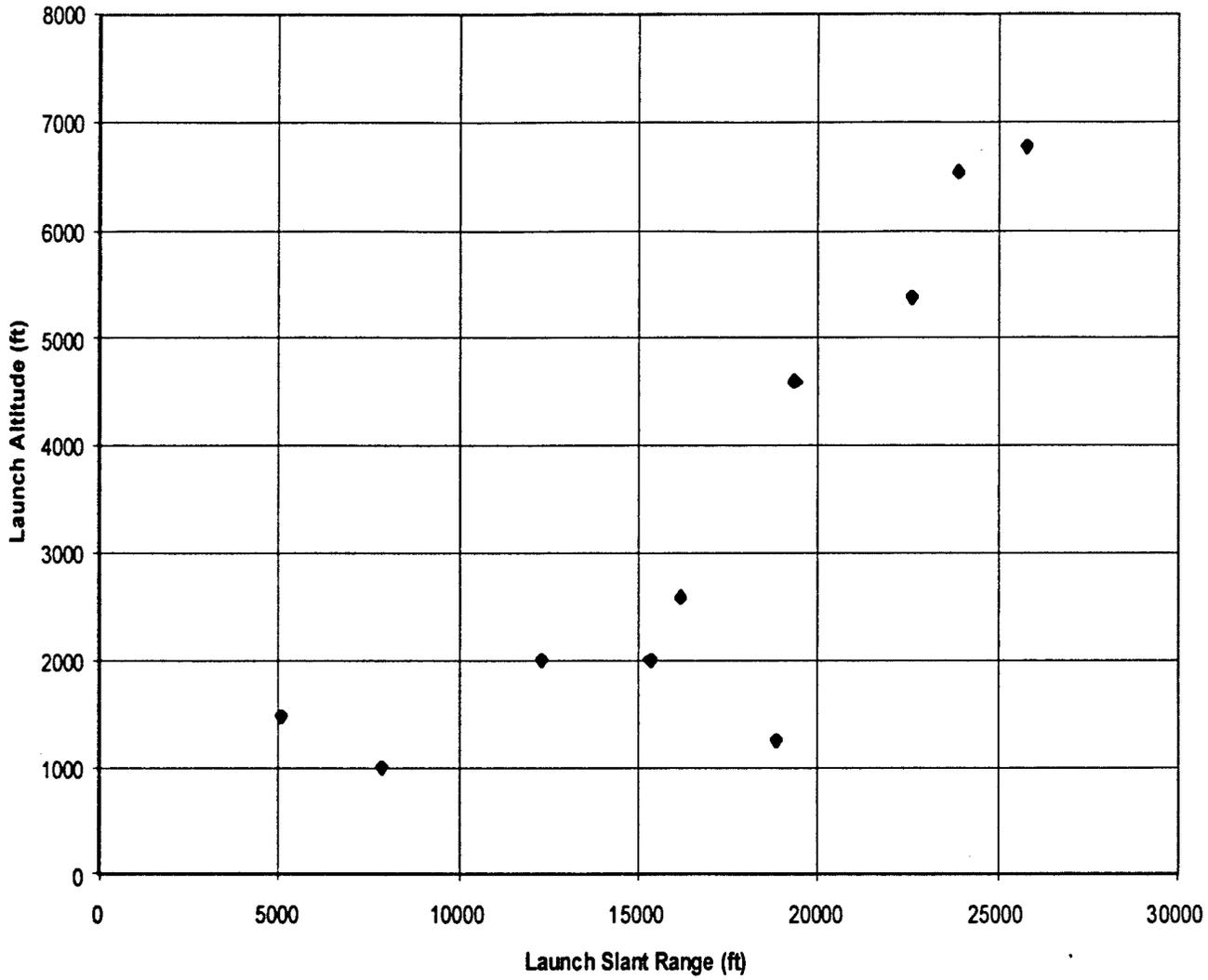


FIGURE 2.1.1

2.2 WSEP 98-06

Table 2.2.1 provides a summary of the missile launch parameters and results for WSEP 98-06.

WSEP 98-06 LAUNCH SUMMARY

WSE P Day	WSEP Callsign	Missile Type	Missile SN	Target Type	Launch Altitude (ft AGL)	Launch Slant Range (ft)	Result	Remarks
1	Hammer 41	AGM-65G	GG04321	Building	11,771	24,928	Miss	Area Track
1	Hammer 42	AGM-65G	GG05527	Building	11,096	27,968	Miss	Area Track
1	Hammer 43	AGM-65G	GG06591	Building	10,857	30,400	Miss	Area Track
1	Hammer 44	AGM-65G	GG06891	Building	10,577	32,224	Miss	Area Track
1	Hammer 45	AGM-65G	GG05500	Building	11,142	26,752	Miss	Area Track
2	Hammer 41	AGM-65D	GD11408	Building	9,500	16,906	Not Assessed	Invalid Tgt
2	Hammer 41	AGM-65G	GG01047	tank	7,285	19,641	Hit	Point Track
2	Hammer 42	AGM-65D	GD09063	tank	7,563	15,898	Miss	
2	Hammer 42	AGM-65D	GD12259	tank	7,331	19,658	Hit	

TABLE 2.2.1

WSEP Day 1 = 1 Jun 98

WSEP Day 2 = 3 Jun 98

Figure 2.0.2 depicts the missile launch parameters for WSEP 98-06.

WSEP 98-06 Launch Summary

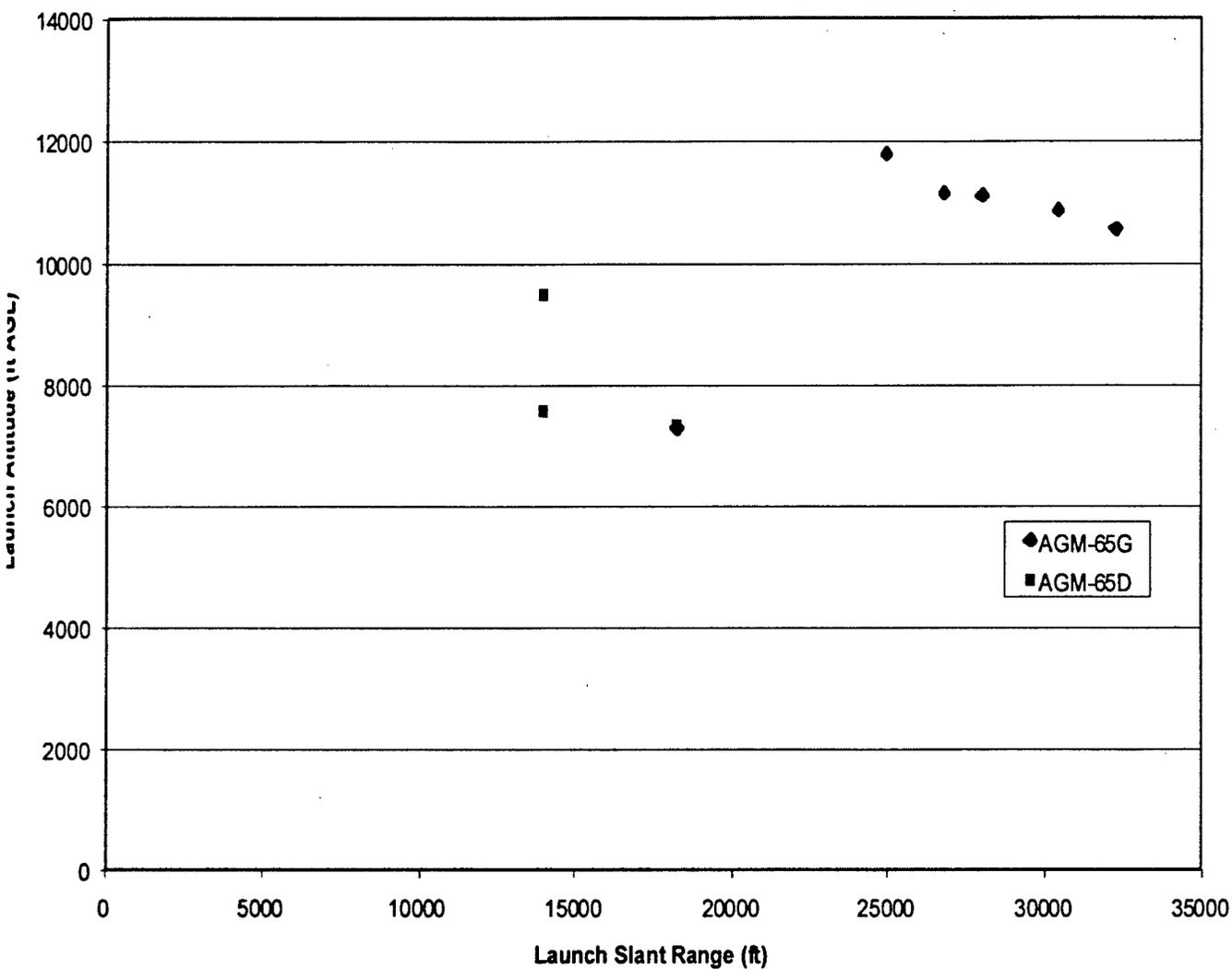


FIGURE 2.2.2

3.0 LAUNCH ANALYSIS

3.1 WSEP 98-03

Twelve AGM-65D Maverick missiles were employed against armor type targets resulting in ten hits, one miss and one no launch. The missile which was not launched (Hammer 11, Day 2) was returned to base for maintenance analysis. The pilot for the aircraft carrying this missile was unable to get missile video on the aircraft Multi Functional Display (MFD). Missile telemetry video was good however, so the most likely cause of this problem was the aircraft or launcher.

The cause of the missile failure during WSEP 98-03 (Hammer 14, Day 2) has been tentatively identified as a circuit card becoming dislodged during the launch acceleration. Figure 3.1.1 shows Hammer 14 video at launch with the missile operating normally. Figure 3.1.2 shows the missile at 2.57 seconds after launch at the apparent failure point. Figure 3.1.2 is the first video field with missing encoded symbology. The other normal symbology (pointing cross, cross-hairs and depression markers) remain but appear to be "frozen". The normal symbology remained "frozen" for the remaining missile time of flight and the missile impacted well off target.

Hammer 14 Video at Launch



Hammer 14 Video at Loss of Symbology (Launch + 2.57 sec)

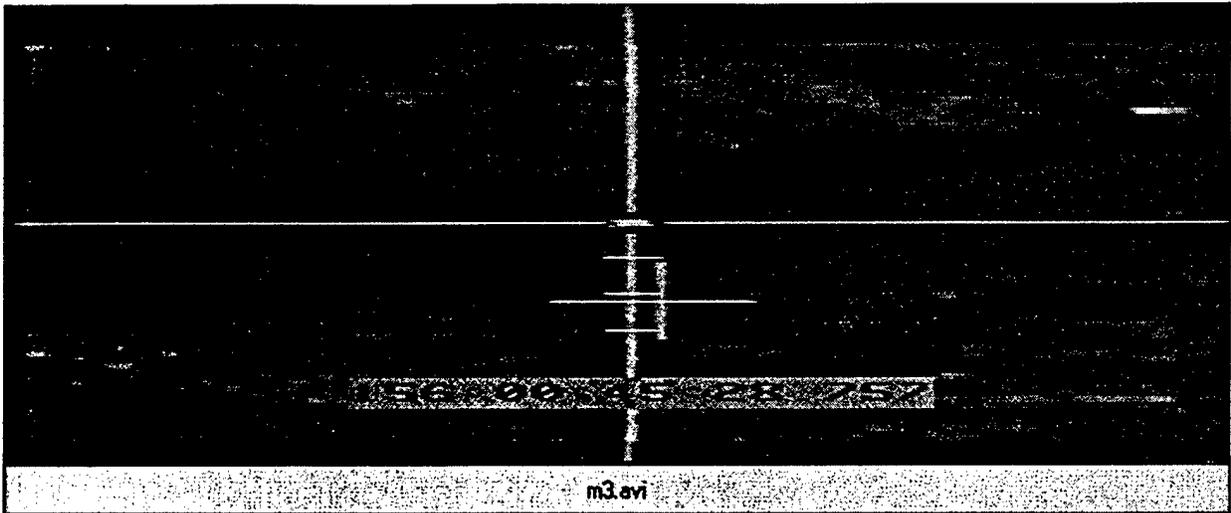


Figure 3.1.2

During past WSEP launches, it has been observed that other AGM-65D and AGM-65B Maverick missiles have experienced failures at approximately this same time after launch (approximately 2.5 seconds). The only known function occurring at this time is the fuse arming function. These previous failures, however, do not appear to be similar to the Hammer 14 failure. Testing conducted at the Guided Weapons Evaluation Facility (GWEF) at Eglin AFB duplicated the Hammer 14 failure mode by removing the CPU card from an operating guidance

unit. Removal of the CPU circuit card simulates the phenomena associated with the card becoming dislocated from its slot. Investigation of this failure is continuing.

3.2 WSEP 98-06

Three AGM-65D missiles were employed against armor targets resulting in one hit, one miss and one "non-assessed". The missile declared "non-assessed" (Hammer 13, Day 2) was launched against an invalid target which should have been removed from the target area prior to the start of the WSEP.

Six AGM-65G missiles were employed resulting in one hit and five misses. The one hit was against an armor type target with the missile launched in the centroid (point track) mode. The five launches assessed as misses were all launched against large size targets (simulated buildings) in the correlate (area track) mode. Two of these missiles hit the targets they were launched against, however these targets were deemed to be incorrect as a result of pilot misidentification and the launches were declared misses. Two of the missiles launched in area track overflowed their intended targets and were declared misses. One missile hit short of its target and was declared a miss.

Review of the system specification for the AGM-65G reveals that the specified accuracy for launches in area track is one milliradian. The five AGM-65G's launched in area track were fired at an average range of 4.7 nm (28,575 ft) against large size targets (simulated buildings). Based upon the one milliradian specified accuracy, it can be expected that the missile would impact within approximately 29 feet of the desired aimpoint. Given that the vertical target height was approximately 40 feet and that the pilot was able to accurately place the missile tracking gate at the centroid of the target, it is possible that the three missiles which missed their targets may have met accuracy specifications (within approximately 29 feet). These missiles may however have missed the desired aimpoint due to inadequate target vertical dimension. Additional analysis should be performed to assess the sensitivity of the AGM-65G area track mode to launch range and target size.

It was observed during one AGM-65G launch (Hammer 41, Day 2) that missile video exhibited a "jittery" motion prior to launch. The pilot also reported that missile video also disappeared momentarily when he commanded field of view changes prior to launch. This "jittery" was also observed on telemetry during missile flyout. Analysis of the missile telemetry and missile video encoded data revealed field to field changes in the video image which produced the "jittery" effect observed. No definitive cause for the "jittery" video was found, however, the most probable cause was a fault within the missile video processing area.

Six AGM-65G missiles were employed resulting in one hit and five misses. The one hit was against an armor type target with the missile launched in the centroid (point track) mode. The five launches assessed as misses were all launched against large size targets (simulated buildings) in the correlate (area track) mode. Two of these missiles hit the targets they were launched against, however these targets were deemed to be incorrect as a result of pilot misidentification and the launches were declared misses. Two of the missiles launched in area track overflowed their intended targets and were declared misses. One missile (also launched in area track) hit short of its target. This missile appeared to be locked onto the ground in front of the target.

Review of the system specification for the AGM-65G reveals that the specified accuracy for launches in area track is one milliradian. The five AGM-65G's launched in area track were fired at an average range of 4.7 nm (28,575 ft) against large size targets (simulated buildings). Based upon the one milliradian specified accuracy, it can be expected that the missile would impact within approximately 29 feet of the desired aimpoint. Given that the vertical target height was approximately 40 feet and that the pilot was able to accurately place the missile tracking gate at the exact centroid of the target, it is possible that the three missiles which missed their targets may have met accuracy specifications (within approximately 29 feet). These missiles most probably missed the target due to inadequate target vertical dimension (+/- 20 feet about target centroid). Figure 3.2.1 on the following page illustrates the lower error limit for seeker crosshair placement on the target that would allow for weapon impact on the target assuming all error was in the "up" direction. It should be noted however that there is just as likely a possibility that all error could have been in the "down" direction which would result in weapon impact significantly short of the target. Therefore, while crosshair placement at the lower error limit would decrease the probability of weapon overflight of the target, it would increase the probability of the weapon impacting short of the target. Additional analysis should

be performed to assess the sensitivity of the AGM-65G area track mode to launch range and target size.

Lower limit for crosshair placement in area track

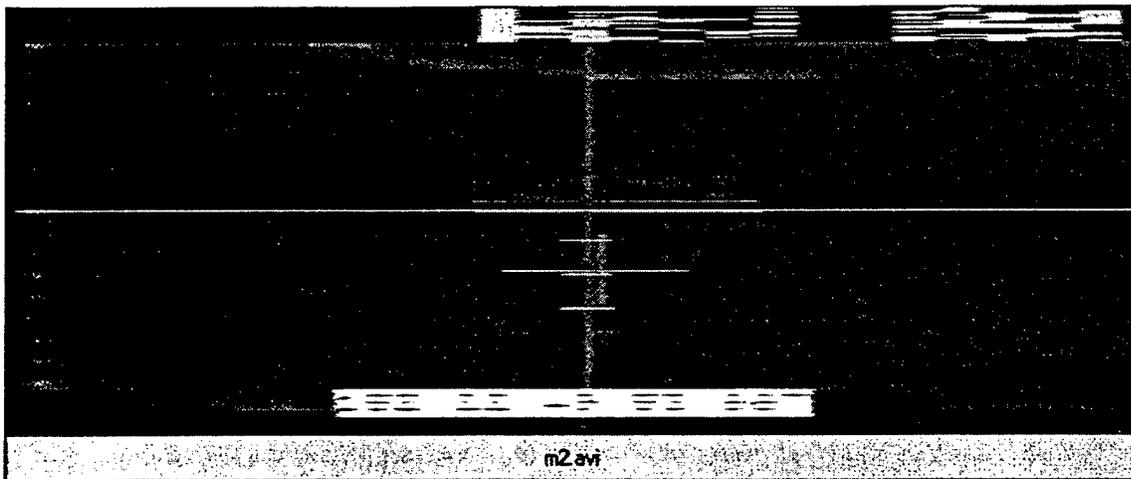


Figure 3.2.1

It was observed during one AGM-65G launch (Hammer 41, Day 2) that missile video exhibited a “jittery” motion prior to launch. The pilot also reported that missile video also disappeared momentarily when he commanded field of view changes prior to launch. This “jitter” was also observed on telemetry during missile flyout. Analysis of the missile telemetry and missile video encoded data revealed field to field changes in the video image which produced the “jittery” effect observed. No definitive cause for the “jittery” video was found, however, the most probable cause was a fault within the missile video processing area, most likely the scan converter memory. Figures 3.2.2 and figure 3.2.3 below are sequential video frames which illustrate this “jitter” phenomena from field to

field. Despite the fact that this phenomena was observed throughout missile flyout, the weapon did impact the target.

First video frame, Hammer 41

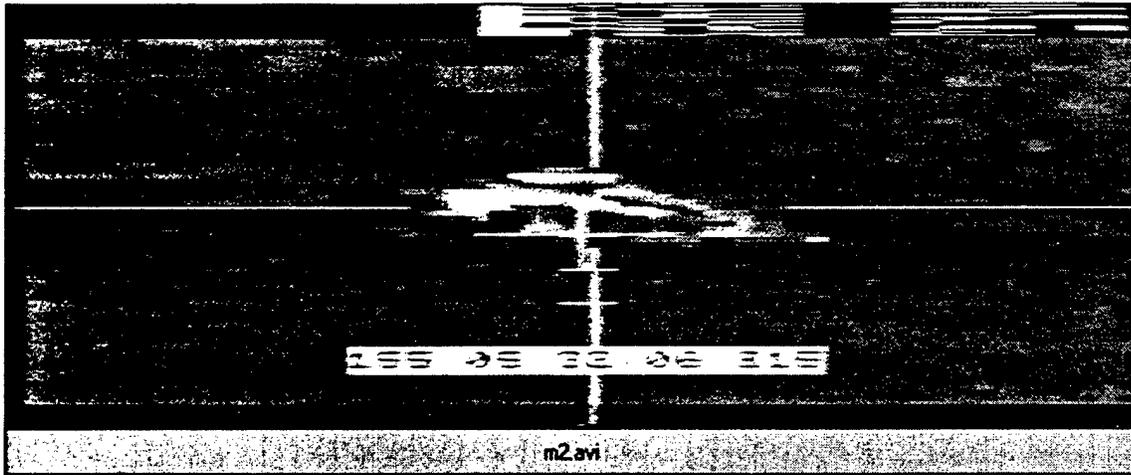


Figure 3.2.2

Following video frame, Hammer 41

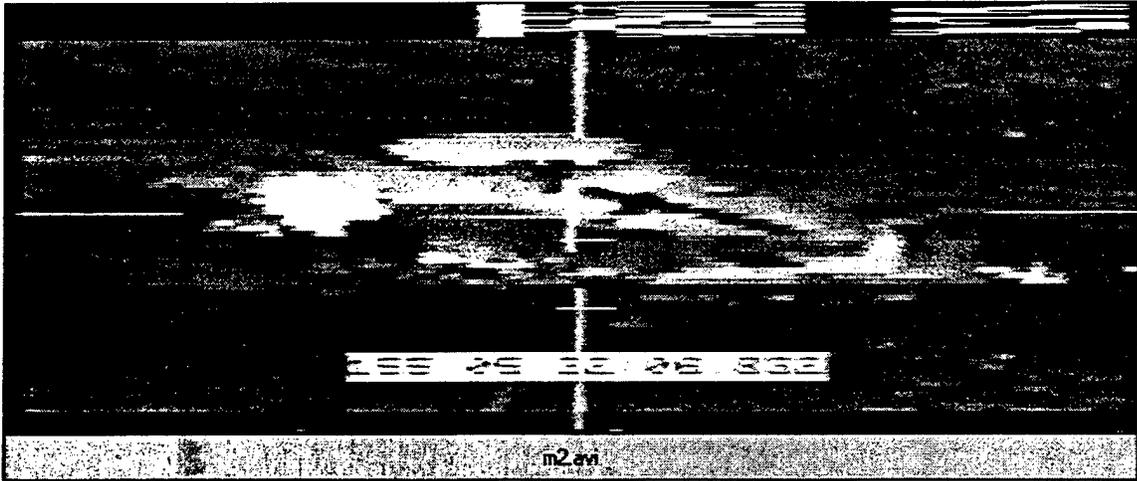
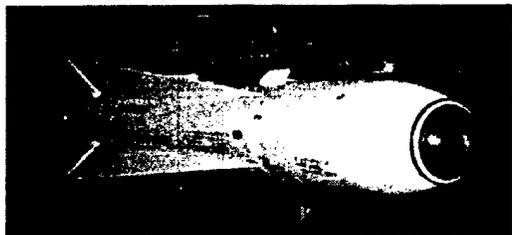


Figure 3.2.3

Schafer

**COMBAT HAMMER
WEAPON SYSTEM EVALUATION
PROGRAM**

**MAVERICK MISSILE LAUNCH ANALYSIS
WSEP 98-10 and WSEP 98-11**



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October 1998

FOREWORD

Schafer Corporation, under contract to the Naval Research Laboratory, is pleased to submit this technical report, Maverick Missile Launch Analysis, WSEP 98-10 and WSEP 98-11, to the 86th Fighter Weapons Squadron (53rd Wing), Air Combat Command, Eglin Air Force Base, Florida and the Maverick Missile System Program Office (OO-ALC/LIWGM), Hill Air Force Base, Utah.

Mr. Sam Matthews, Senior Systems Engineer, and Mr. Steve Madley, Senior Systems Engineer, prepared this report at Schafer Corporation's Ft. Walton Beach, Florida facility.

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1.0 EXECUTIVE SUMMARY

The 86th Fighter Weapons Squadron (53rd Wing/Air Combat Command) conducted an evaluation of the AGM-65 Maverick Missile System as part of the USAF Air-to-Ground Weapon System Evaluation Program (WSEP 98-10 and 98-11) from 3-6 August 1998 at the Utah Test and Training Range (UTTR). F-16 aircraft, aircrews and maintenance personnel from the 34th Fighter Squadron (388th Fighter Wing/Hill AFB, UT) participated in WSEP 98-10. F-16 aircraft, aircrews and maintenance personnel from the 524th Fighter Squadron (27th Fighter Wing/Cannon AFB, New Mexico) participated in WSEP 98-11.

Twelve AGM-65D Maverick missiles and twelve AGM-65G Maverick missiles were employed by the 34th Fighter Squadron during WSEP 98-10. Twelve AGM-65D Maverick missiles were employed by the 524th Fighter Squadron during WSEP 98-11.

All twenty-four of the AGM-65D Maverick missiles were employed against tank type targets. Twenty-two of these missiles were launched from the aircraft resulting in fourteen hits and eight misses. Two missiles failed to launch due to aircraft malfunctions prior to takeoff.

Twelve AGM-65G Maverick missiles were launched against large size targets (simulated buildings) resulting in eight hits and four misses. All eight hits were with missiles launched in the point track (centroid track) mode. Of the four missiles classified as misses, two were launched in the area track mode and two were launched in the point track mode. The two missiles launched in area track that missed their targets exhibited a previously documented AGM-65G problem associated with the one milliradian tracking accuracy specification of the missile in area track. One miss in the point track mode was attributed to a target break lock condition just after launch. One miss in the point track mode was the result of target misidentification, however, it was observed that this missile exhibited target overflight characteristics.

2.0 LAUNCH SUMMARY

2.1 WSEP 98-10

Table 2.1.1 summarizes missile launch parameters and results for WSEP 98-10.

WSEP 98-10 LAUNCH SUMMARY

WSE P DAY	WSEP Callsign	Missile Type	Missile SN	Target Type	Launch Altitude (ft MSL)	Launch Slant Range (ft)	Result	Remarks
1	Hammer 41	AGM-65D	2000084	tank	11,250	24,320	Hit	
1	Hammer 42	AGM-65D	GD09078	tank	9,340	10,336	Miss	Clearance
1	Hammer 43	AGM-65D	GD04054	tank	7,200	7,296	Hit	No TM
1	Hammer 43	AGM-65D	GD12246	tank	10,600	14,592	Miss	Target track
1	Hammer 44	AGM-65D	GD12409	tank	11,000	42,560	Miss	Target track
1	Hammer 42	AGM-65D	GD12229	tank	8,340	18,848	Hit	
1	Hammer 45	AGM-65D	GD09294	tank	12,400	21,888	Hit	No TM
1	Hammer 46	AGM-65D	GD13498	tank	14,200	31,008	Hit	
1	Hammer 45	AGM-65D	GD12251	tank	10,000	14,592	Hit	
1	Hammer 46	AGM-65D	GD11573	tank	5,500	12,160	Miss	Missile fail
2	Hammer 43	AGM-65G	GG06982	building	11,600	17,024	Hit	Point track
2	Hammer 44	AGM-65G	GG056561	building	9,570	12,768	Hit	Point track
2	Hammer 42	AGM-65G	GG00153Y	building	10,500	14,592	Miss	Point track Break lock
2	Hammer 41	AGM-65G	GG05910	building	11,040	9,728	Miss	Point track Overflight
2	Hammer 45	AGM-65G	GG06911	building	9,600	32,224	Miss	Area track 1 MR spec
2	Hammer 46	AGM-65G	GG06622	building	9,200	16,416	Miss	Area track 1 MR spec

WSEP 98-10 LAUNCH SUMMARY (continued)

WSEP DAY	WSEP Callsign	Missile Type	Missile SN	Target Type	Launch Altitude (ft MSL)	Launch Slant Range (ft)	Result	Remarks
3	Hammer 41	AGM-65G	GG06992	building	11,800	19,456	Hit	Point track
3	Hammer 42	AGM-65G	GG05507	building	13,000	28,576	Hit	Point track
3	Hammer 43	AGM-65G	GG06975	building	14,900	45,600	Hit	Point track
3	Hammer 44	AGM-65G	GG06996	building	13,540	38,304	Hit	Point track
3	Hammer 45	AGM-65G	GG05542	building	9,600	60,800	Hit	Point track
3	Hammer 46	AGM-65D	GD08314	tank	7,580	13,376	Hit	
3	Hammer 45	AGM-65G	GG06997	building	9,300	30,400	Hit	Point track
3	Hammer 46	AGM-65D	GD12281	tank	8,180	20,672	Hit	

TABLE 2.1.1

WSEP Day 1 = 3 Aug 98

WSEP Day 2 = 4 Aug 98

WSEP Day 3 = 5 Aug 98

Figure 2.1.1 depicts the AGM-65D missile launch parameters for WSEP 98-10.

**AGM-65D Launch Parameters
WSEP 98-10**

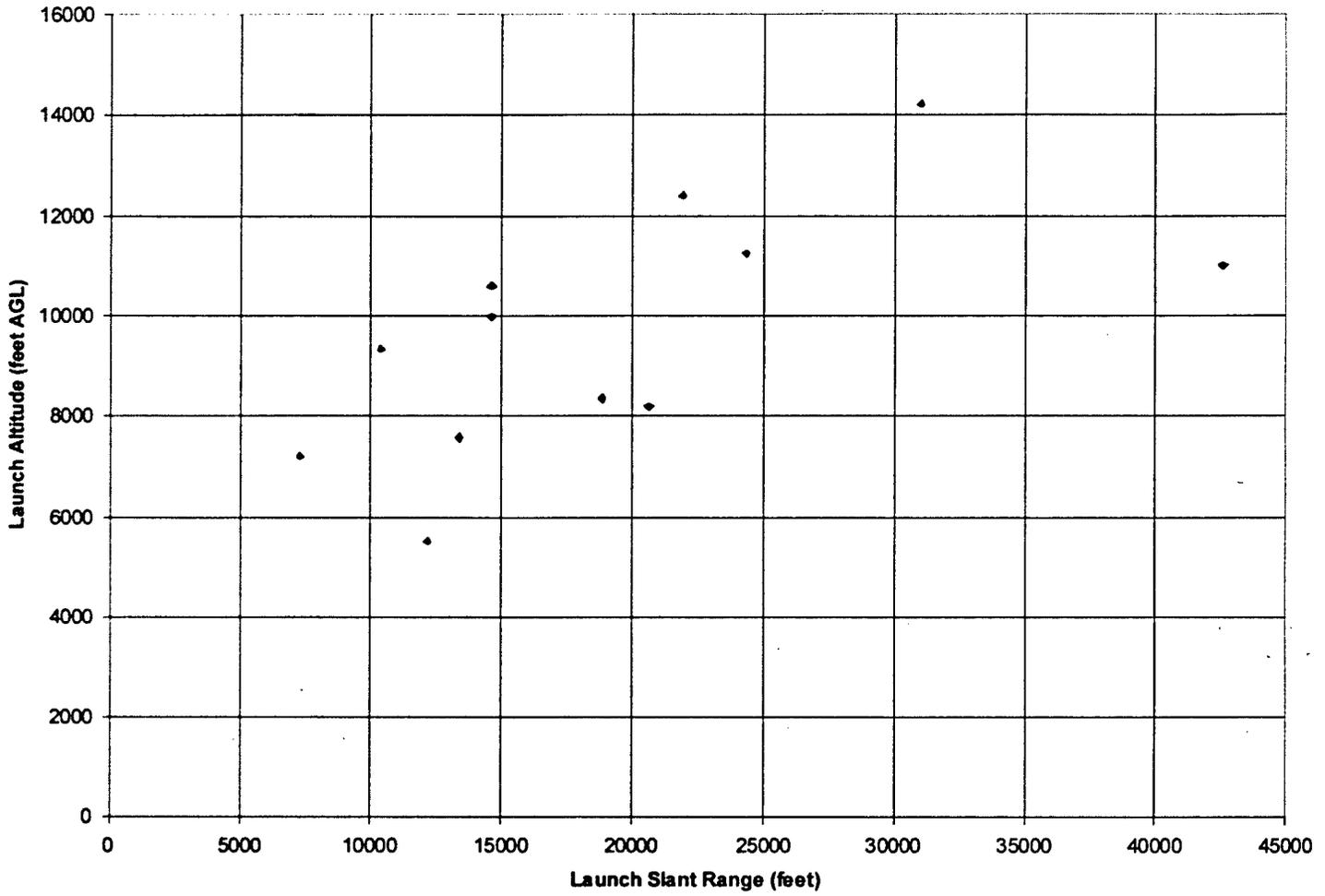


Figure 2.1.1

Figure 2.1.2 depicts the AGM-65G missile launch parameters for WSEP 98-10.

**AGM-65G Launch Parameters
WSEP 98-10**

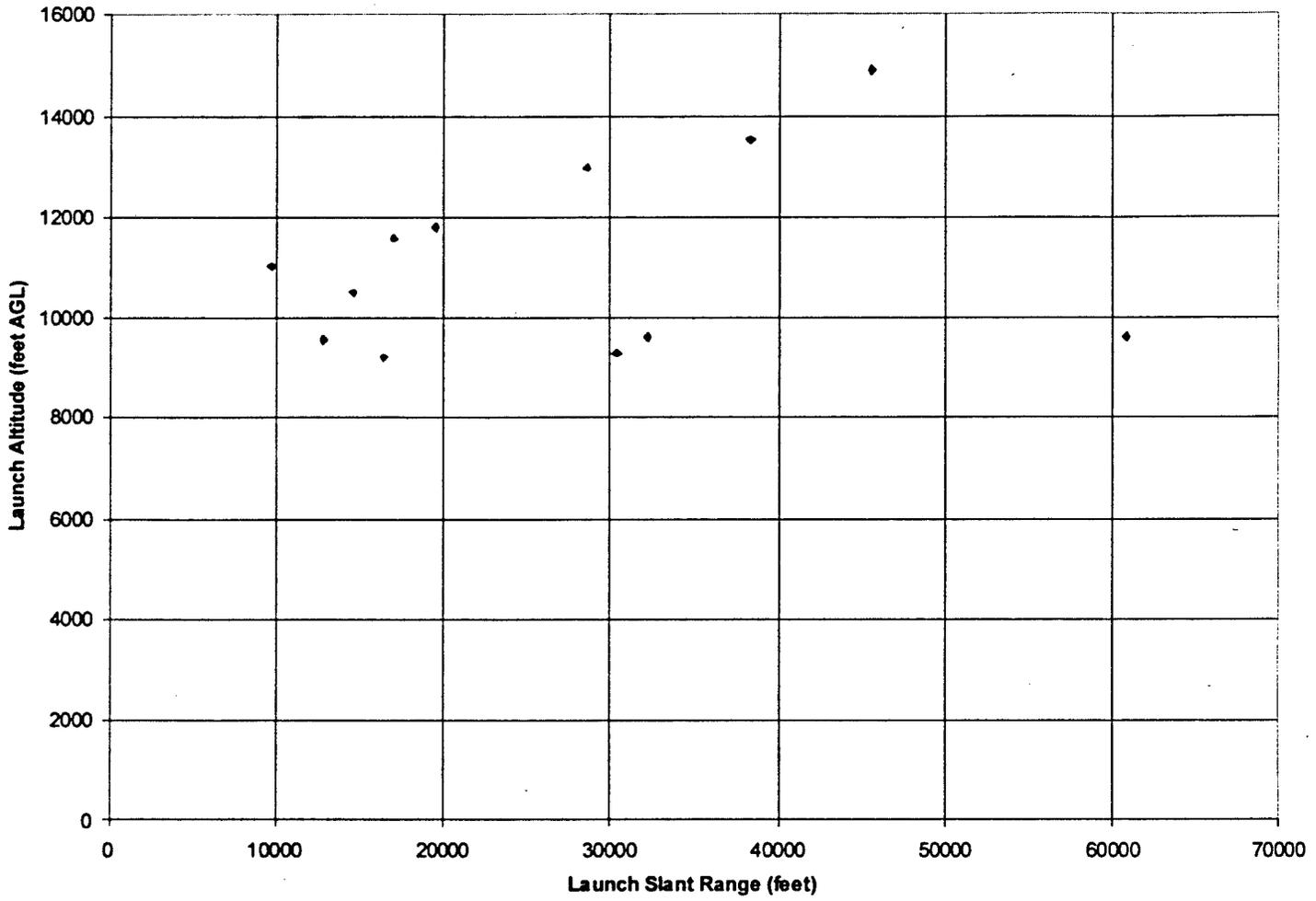


Figure 2.1.2

2.2 WSEP 98-11

Table 2.2.1 summarizes missile launch parameters and results for WSEP 98-11.

WSEP 98-11 LAUNCH SUMMARY

WSEP Day	WSEP Callsign	Missile Type	Missile S/n	Target Type	Launch Altitude (ft MSL)	Launch Slant Range (ft)	Result	Remarks
1	Hammer 31	AGM-65D	GD09241	tank	9,350	2.2	Hit	
1	Hammer 32	AGM-65D	GD09278	tank	9,710	3.5	Miss	Break lock
1	Hammer 33	AGM-65D	GD08324	tank	7,200	2.3	Hit	
1	Hammer 34	AGM-65D	GD09263	tank	9,260	2.9	Hit	
1	Hammer 35	AGM-65D	GD09268	tank	10,580	3.8	Miss	Missile Fail
1	Hammer 36	AGM-65D	GD08307	tank	9,740	2.9	Miss	-Target ID
2	Hammer 31	AGM-65D		NA	NA	NA	NA	Ground Abort
2	Hammer 32	AGM-65D	GD012179	tank	10,500	3.7	Hit	
2	Hammer 33	AGM-65D	GD09283	tank	9,400	3.3	Miss	Missile Fail
2	Hammer 34	AGM-65D	GD09236	tank	5,900	1.5	Hit	
2	Hammer 35	AGM-65D	GD09290	tank	9,300	1.7	Hit	
2	Hammer 36	AGM-65D		NA	NA	NA	NA	Ground Abort

TABLE 2.2.1

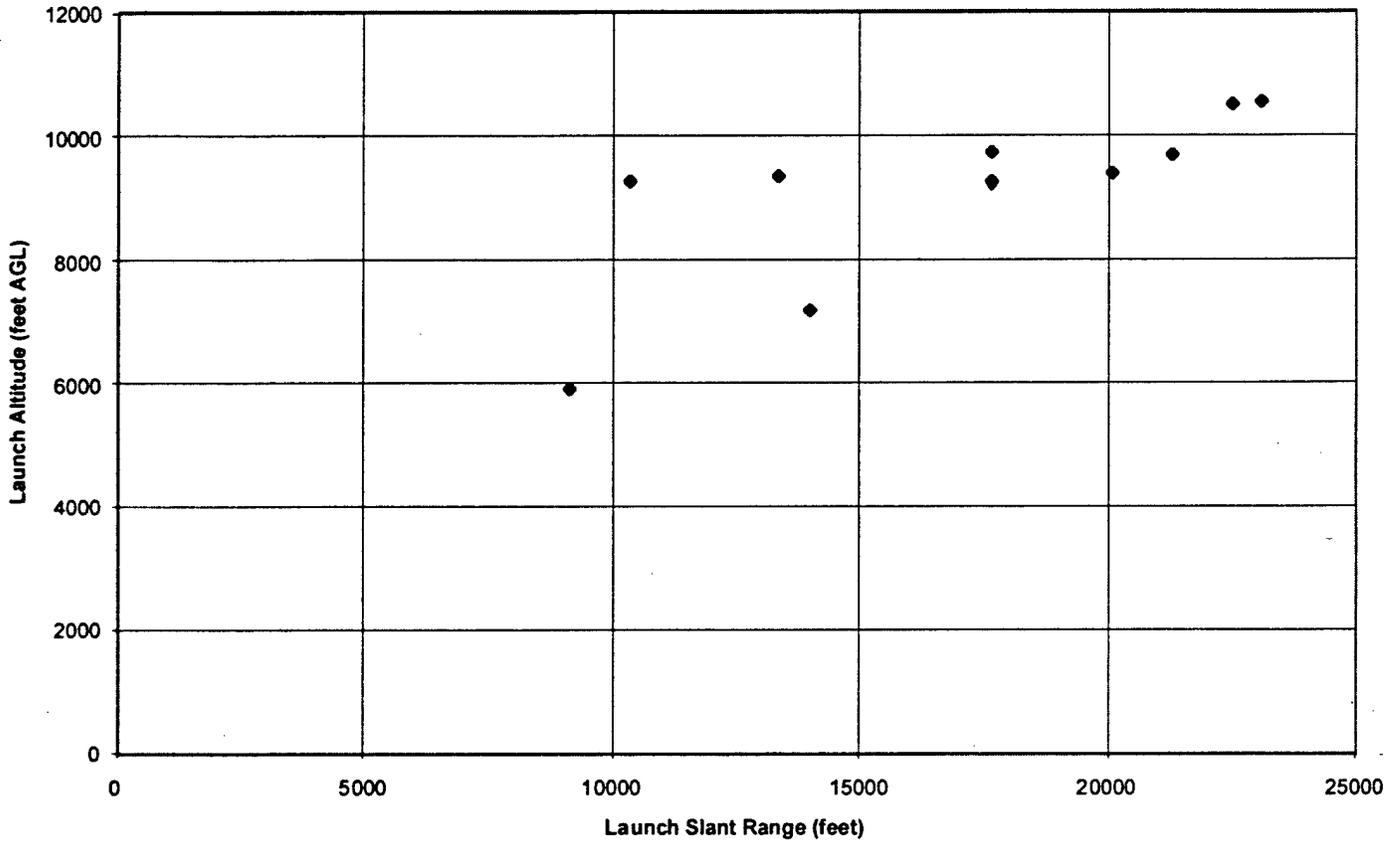
WSEP Day 1 = 3 Aug 98

WSEP Day 2 = 4 Aug 98

Figure 2.2.1 depicts the AGM-65D missile launch parameters for WSEP 98-11.

Figure 2.2.1

**AGM-65D Launch Parameters
WSEP 98-11**



3.0 LAUNCH ANALYSIS

3.1 WSEP 98-10

Twelve AGM-65D Maverick missiles were employed during WSEP 98-10 resulting in eight hits and four misses. All missiles were employed against tank size targets. One AGM-65D failure (Hammer 42, Day 1) was attributed to aircrew error when the missile was launched prior to receiving range clearance to fire. Two missiles (Hammer 43, Day 1 and Hammer 43, Day 1) were declared misses as the result of the missile tracking incorrect targets (hot spots/fires in vicinity of actual targets). One missile (Hammer 46, Day 1) missed for unexplained reasons. Problems with telemetry data from some missiles hampered failure analysis.

Twelve AGM-65G Maverick missiles were employed against large size targets during this WSEP resulting in eight hits and four misses. The large size targets were simulated buildings constructed of stacked sea containers. Two of the four misses (Hammer 45, Day 2 and Hammer 46, Day 2) can be attributed to the one-milliradian accuracy specification of the AGM-65G in area track. In both cases, the missiles were locked onto the simulated building in area track and over flew the target. The details of this problem are discussed in the Maverick Missile Launch Analysis report for WSEP 98-03 and 98-06 (July 1998).

One AGM-65G miss (Hammer 41, Day 2) occurred when the missile was erroneously locked onto a piece of debris from a previously attacked simulated building. The lock on to this piece of debris was in point track mode and the missile over flew the target.

One missile (Hammer 42, Day 2) broke lock on at or just after launch. The telemetry data for this missile is incomplete; therefore no definitive cause of the break lock was determined. Figures 3.1.1 through 3.1.3 are the only video frames available of the break lock sequence for this missile. Note in Figure 3.1.1 that there are multiple targets within the tracking gates. In Figure 3.1.2 the

targets have shifted slightly. In Figure 3:1.3 the tracking gates have closed and the targets have moved below the gates.

Hammer 42 Break Lock Video (First Frame)

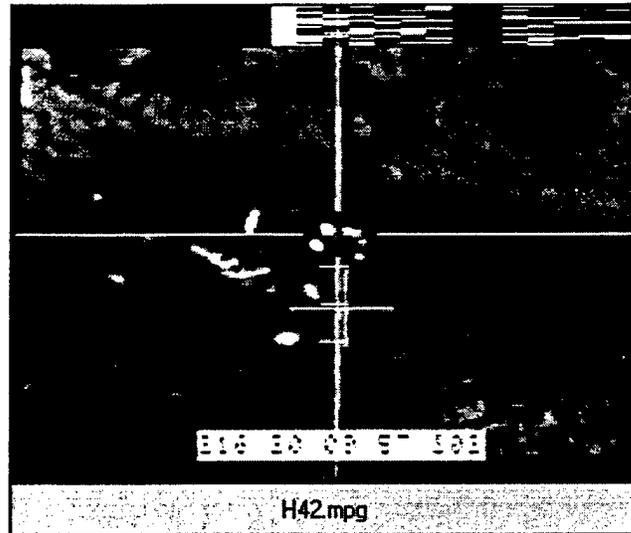


Figure 3.1.1

Hammer 42 Break Lock Video (Second Frame)

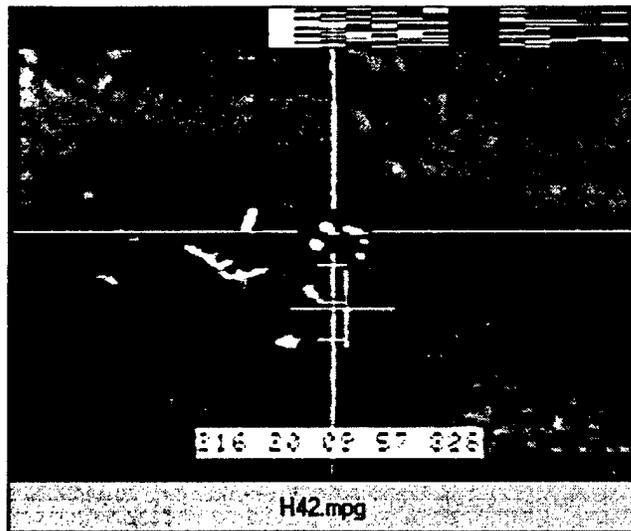


Figure 3.1.2

Hammer 42 Break Lock Video (Third Frame)

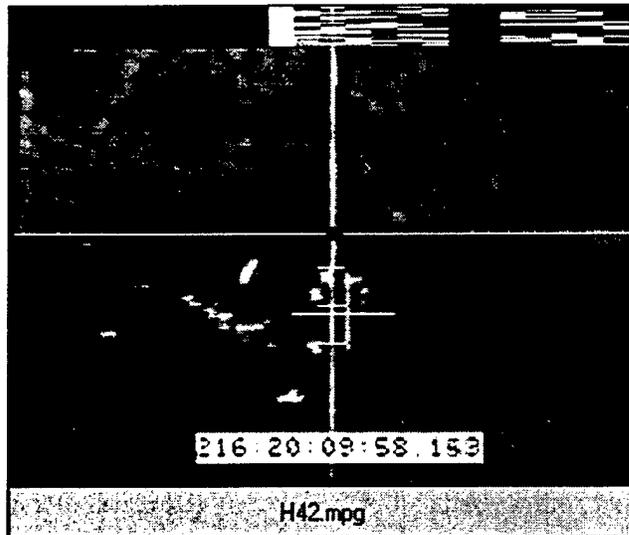


Figure 3.1.3

During post flight debriefings it was noted that some pilots were not familiar with the 1-milliradian accuracy specification of the AGM-65G in area track. They believed that it is operationally desirable to launch against large targets in area track rather than point track. They also believed the AGM-65G would over fly most targets (both large and small) in point track.

3.2 WSEP 98-11

Twelve AGM-65D Maverick missiles were employed resulting in six hits, four misses and two aircraft ground aborts prior to takeoff. One miss (Hammer 36, Day 1) was attributed to target misidentification. One miss (Hammer 32, Day 1) was caused a break lock condition at launch. Two of the failures (Hammer 35, Day 1 and Hammer 33, Day 2) appear to be the result of Power Supply Assembly (PSA) circuit cards becoming dislodged during launch acceleration.

Telemetry and video data for the Hammer 32, Day 1 launch were analyzed to determine the cause of the break lock condition. Review of this data indicates that the break lock was caused by excessive apparent target motion. Figures 3.2.1 through 3.2.5 below illustrate the apparent target motion.

Figure 3.2.1 depicts normal target tracking.

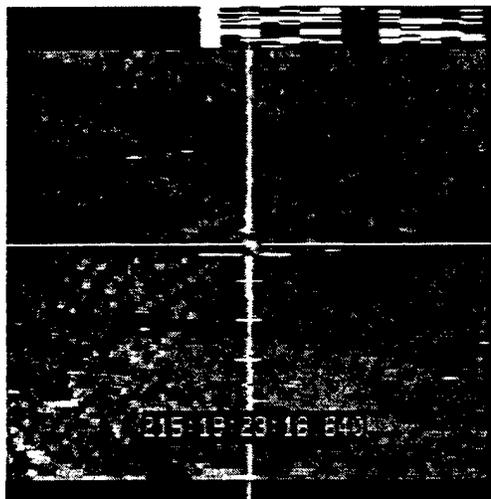


Figure 3.2.1

Figure 3.2.2 (0.016 sec later) shows that the target has moved to the upper right portion of the tracking gate.

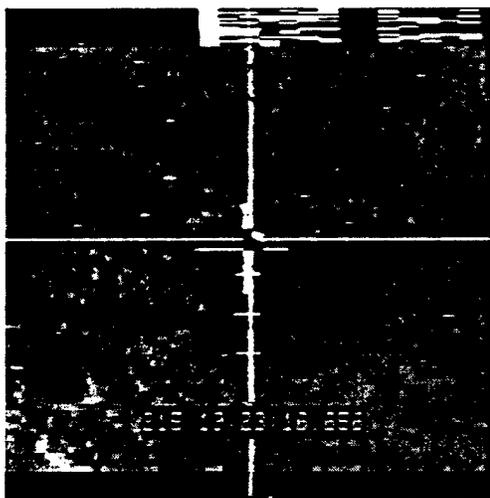


Figure 3.2.2

Figure 3.2.3 (0.017 sec later) shows that the target has moved to the lower portion of the tracking gate.

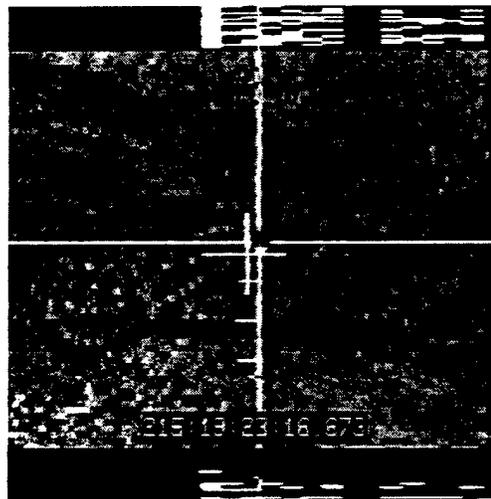


Figure 3.2.3

Figure 3.2.4 (0.017 sec later) shows the missile has invoked the ATA algorithm to recapture the target. In this video frame, sync tearing was observed at the top of the frame indicating possible gyro precession.

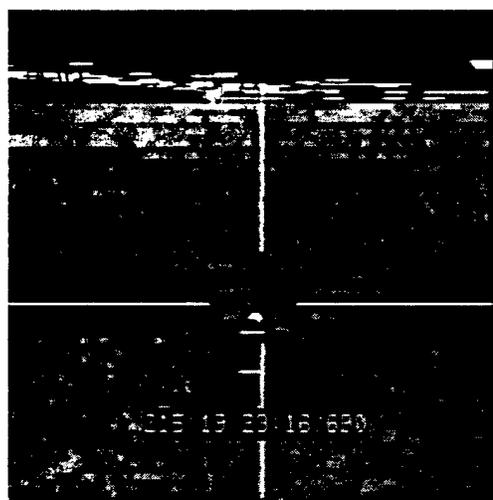


Figure 3.2.4

Figure 3.2.5 (0.033 sec later) shows that the target has moved outside of the tracking gate and the missile has broken lock.

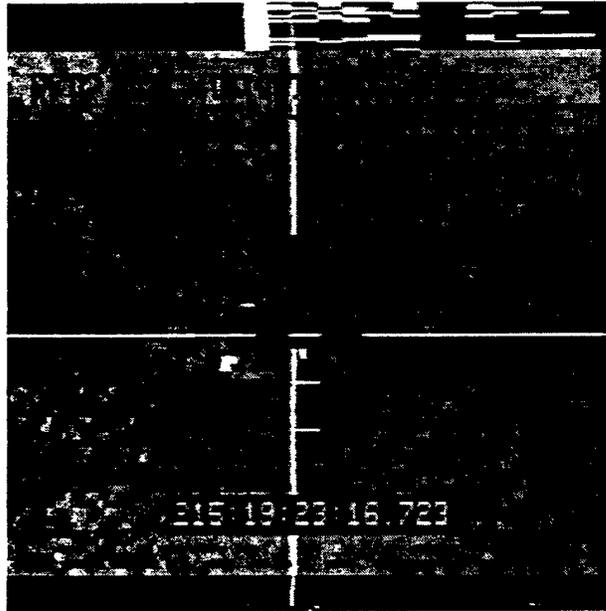


Figure 3.2.5

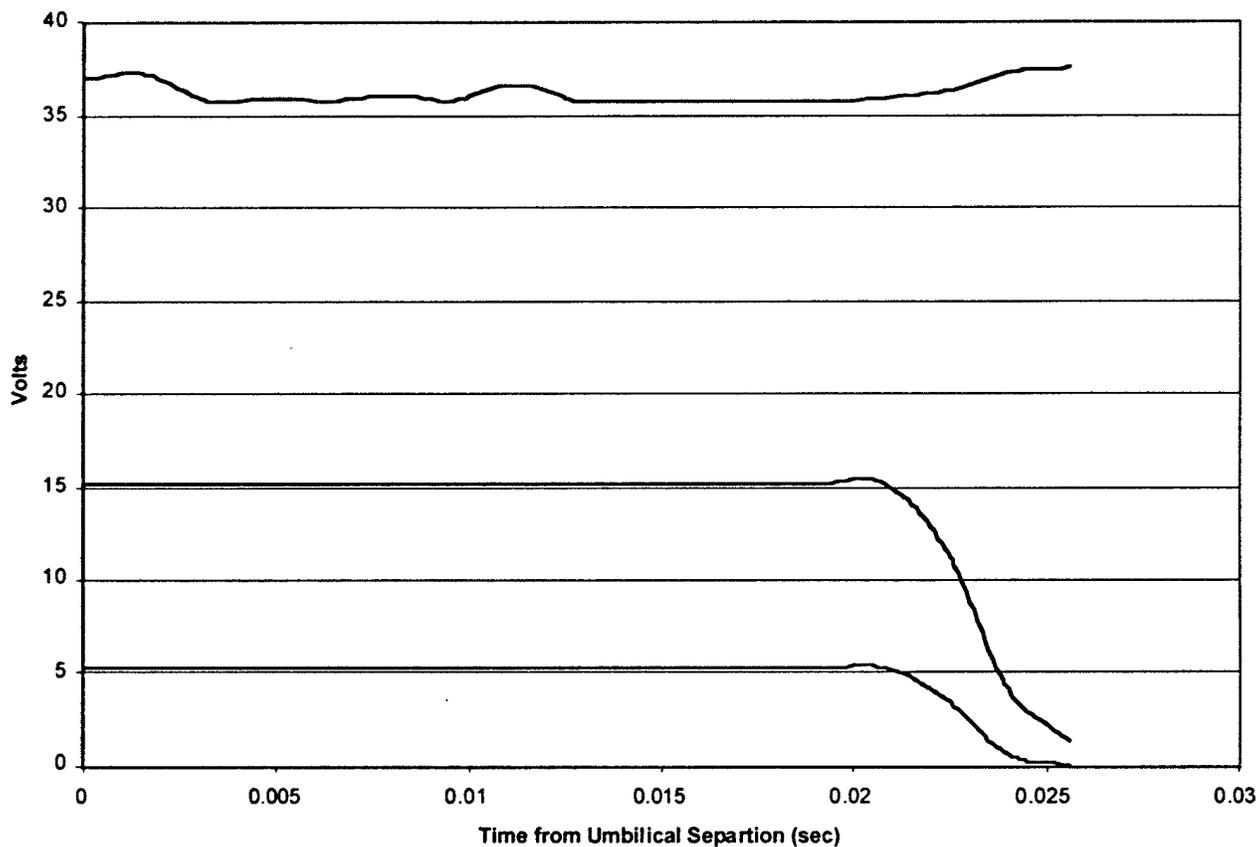
The most likely cause for the apparent target motion observed in this launch is a failure of the Missile Restraint Device (MRD) on the LAU-117 launcher to release at its designed release force. Most likely it released at a much higher force resulting in an excessive moment force on the missile at launch which translated into an apparent target motion. This problem was observed during AGM-65H QOT&E launches from the LAU-117 as well as other firings. At the present time there is no field check of the LAU-117 MRD. The only time the release force is checked is when the launcher is returned to the depot for maintenance.

Hammer 35, Day 1 and Hammer 33, Day 2 both exhibited a similar failure mode. Telemetry and video data for these missiles were analyzed to determine the most likely failure. In each case it

was observed that both the 5-volt late and 15-volt late power supply values simultaneously went to 0 volts almost immediately after weapon umbilical separation. In both cases the missile battery voltage remained stable.

Hammer 35's failure occurred at approximately 22 milliseconds after umbilical separation, and Hammer 33's failure occurred at approximately 60 milliseconds after umbilical separation. Figures 3.2.6 and 3.2.7 respectively show Hammer 35 and Hammer 33 power supply values immediately after umbilical separation.

Hammer 35 Power Supply Values



Hammer 33 Power Supply Values

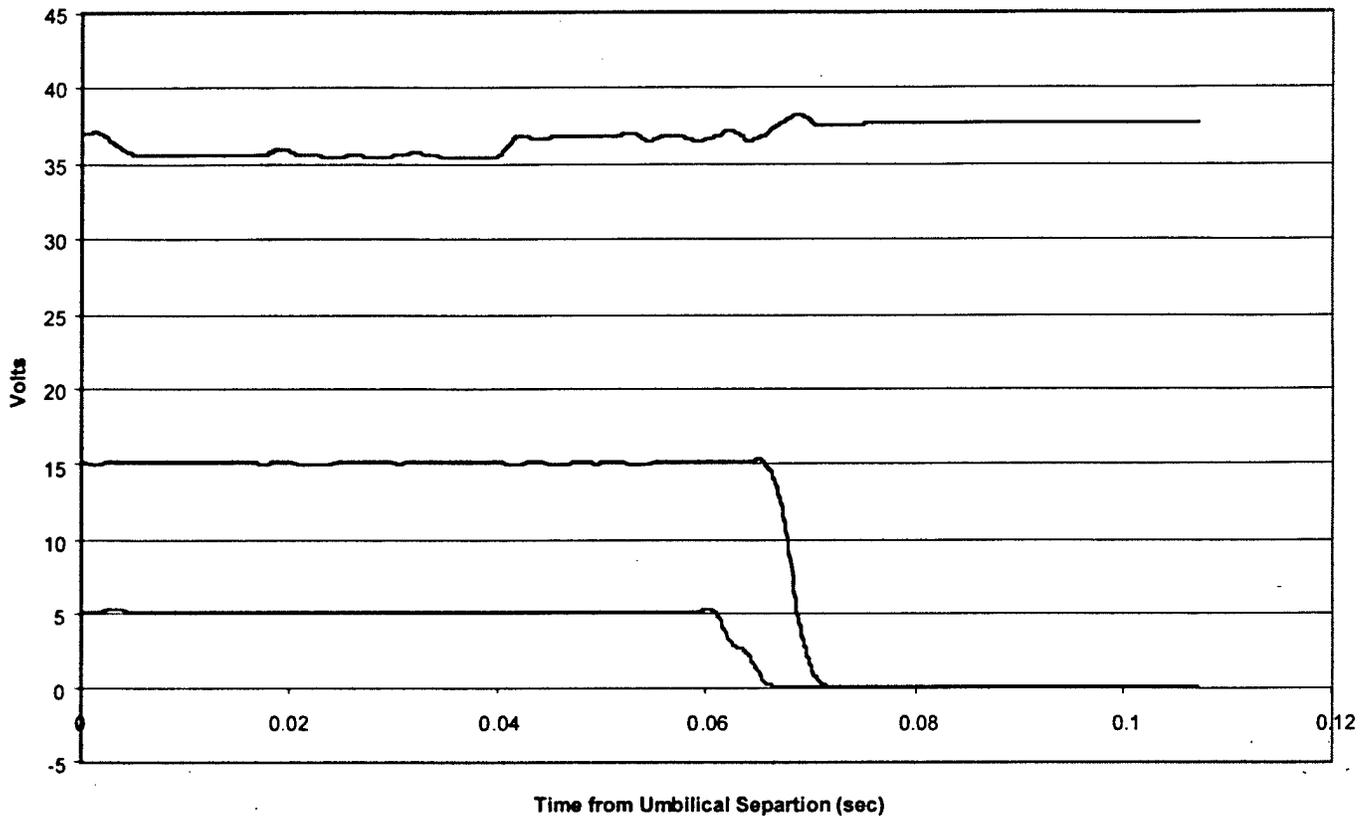


Figure 3.2.7

This failure mode is similar to failures observed in AGM-65G missiles where circuit cards were dislodged during launch acceleration. For the two failures under investigation, it was concluded that the Power Supply Assembly (PSA) circuit cards were dislodged shortly after launch. In both the AGM-65D and the AGM-65G missile, the PSA card is the heaviest card (approximately 1.5 lbs.) in the card assembly. It has also been observed in previous missile firings that AGM-65G torquer amplifier cards have become dislodged at or shortly after launch.

In the case of the AGM-65G, the failures tended to occur at a slightly later time after umbilical separation. This can be attributed to the slightly lower launch acceleration forces for the AGM-65G (approximately 17 g's for the AGM-65G vice approximately 22.5 g's for the AGM-65D). During WSEP98-03, a similar failure was observed in the launch of an AGM-65D missile. This failure (WSEP 98-03) was duplicated in the Guided Weapons Evaluation Facility (GWEF) at Eglin AFB, Florida by dislodging a CPU card after umbilical separation.

During production of the AGM-65G, an engineering change was made to the missile that removed the circuit card retainer plate. The common factor observed in the majority of the AGM-65G failures at launch, or shortly thereafter, is the lack of this circuit card retainer plate. While it is common knowledge that many AGM-65G Maverick missiles were produced without the card retainer plate, it was not generally known how many, if any, AGM-65D Maverick missiles were produced without the retainer plate. A search of available Air Force databases revealed that approximately 1300 AGM-65D Maverick missiles have been produced without the circuit card retainer.

Figure 3.2.8 illustrates the AGM-65D/G circuit card installation without the retainer plate. The Power Supply Assembly (PSA) card is the bottom card behind the cables. The Torquer Amplifier card is the right-most card.

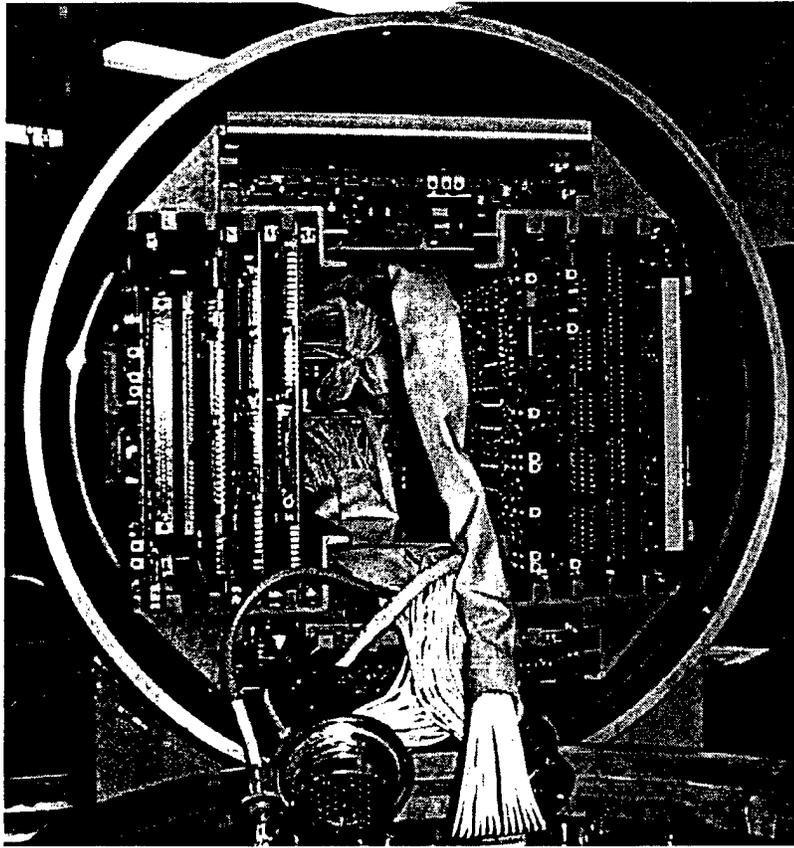


Figure 3.2.8

The lack of the circuit card retainer card in some AGM-65D missiles may contribute to an increased failure rate as the inventory is depleted and later year manufactured missiles are expended.