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PRELIMINARY EVALUATION OF THE FLAT TRAJECTORY PROJECTILE (FTP) --ETC(U)
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(12) LEVEL II

TECHNICAL REPORT T-79-51

PRELIMINARY EVALUATION OF THE FLAT TRAJECTORY PROJECTILE (FTP) CONCEPT

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U.S. ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND

Redstone Arsenal, Alabama 35809

7 May 1979

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: TR T-79-51
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): (6) Preliminary Evaluation of the Flat Trajectory Projectile (FTP) Concept
5. TYPE OF REPORT & PERIOD COVERED: (9) Technical Report
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): (10) Charles L. Lewis
8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Commander
US Army Missile Research and Development Command
Attn: DRDMI-T&E
Redstone Arsenal, Alabama 35809

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
(12) 22p.

11. CONTROLLING OFFICE NAME AND ADDRESS
Commander
US Army Missile Research and Development Command
Attn: DRDMI-TI
Redstone Arsenal, Alabama 35809

12. REPORT DATE: 7 May 1979
13. NUMBER OF PAGES: 23

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release;
Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

FTP
M 72 LAW
VIPER
INERTIAL SET BACK GYRO

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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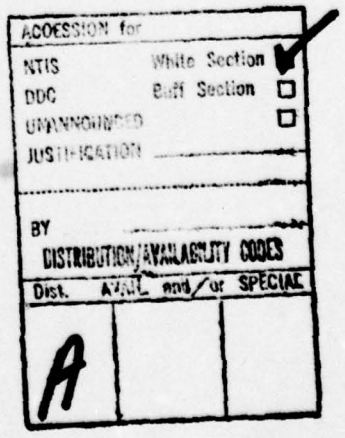

ILLUSTRATIONS

1. INTRODUCTION

MIRADCOM was recently requested via DARCOM TWIX to study a flat trajectory projectile (FTP) concept proposed by the Naval Surface Weapon Center. In this concept, a nose-mounted lifting surface is utilized to reduce the gravity drop of an unguided rocket such as the M72 LAW or VIPER, thereby effecting a flattened trajectory with little or no dependence or range estimation. (See Appendix A.)

As originally proposed by the NAVY, this lifting surface would be roll stabilized via a single degree of freedom gyro to keep the lift force in the vertical plane. This unit would attach to a projectile without altering the design, and this would comprise a simple retrofit. The resulting projectile trajectories would be essentially flat (less than 1 ft) for approximately 250 meters, thereby eliminating any range — dependent sight setting changes as currently required. The weight of the FTP would be ~0.2 pounds, and the cost would be five or six dollars.

In response to the DARCOM request, an evaluation group was formed by MIRADCOM's Technology Laboratory to evaluate the FTP concept. The prime members of this group and their respective disciplines are:

- Russ Gambill — Team Leader
- Charles Lewis — Systems Analysis
- Larry Murdock — Simulation
- Roy Pugh — Gyro
- David Washington — Aerodynamics

2. METHOD OF EVALUATION

The following evaluation procedure was adopted. First, the Navy (Bill Piper, NAVSURFWPNCEN) was contacted and questioned concerning any additional Navy FTP activities. Second, MIRADCOM developed independent estimates of the proposed feasibility and ultimate cost of the FTP hardware. Third, preliminary simulation studies were performed to determine basic concept feasibility.

Possible warhead degradation due to the front mounted FTP was outside the scope of this study. However, even small degradations may be significant to the smaller anti-tank projectile and should be evaluated via comparative warhead hardware tests early in any FTP program.

3. RESULTS

In telephone conversations with the Navy's Bill Piper, the designer of the FTP, it was determined that:

- Recent attempts by the Navy to demonstrate FTP inertial set-back gyro spin-up under realistic field conditions have failed. The inertial spin-up idea has since been abandoned by the Navy. The Navy has a small inhouse effort underway to evaluate a hot gas spin-up mechanism for the gyro.

- The concept feasibility rounds fired by the Navy were not performed with the lift mechanism hardware packaged as shown in the FTP design concept sketch (Appendix A, *Figure A2*). Instead, the gyro, spin-up apparatus, and other parts, were mounted in a special hollow section of the warhead. Thus, no actual hardware mechanism of the FTP concept in the nose-mount retrofit configuration has yet been constructed.

- The NAVY feasibility flights were performed with expensive bearings, etc.

- According to Bill Piper, the Navy performed some warhead degradation tests utilizing M72 LAW warheads and some dummy FTP units with the approximate proper mass. Four to six warheads were involved, with part of the warhead fired through the dummy FTP units, and part of them fired without any obstructions. The results of the test, which were not documented, indicate only small (~5%) degradation of the warhead performance due to the FTP obstruction.

An in-house MIRADCOM evaluation of hardware feasibility and cost determined:

- Off-the-shelf single degree-of-freedom TIMEX gyros will meet Navy concept size, and momentum requirements.

- Gyro spin-up mechanism in nose-mount retrofit configuration is unclear (Appendix A, *Figure A2*). Techniques such as launcher mounted gas bottle, doughnut-shaped gas bottle internal to nose-mounted FTP, etc., may work but are much more complex and expensive than original inertial set-back spin-up technique Navy proposed but could not demonstrate in the field.

- Due to coupling of vertical lift into lateral plane when rocket roll occurs, the nose-mounted FTP unit must be maintained in vertical position, within ±5° of true vertical (as indicated by simulation) to achieve the desired lateral plane accuracy. Current direct fire (unguided) weapons require no particular roll orientation as they are loaded into the tube launcher during assembly. Incorporation of the FTP nose would add the requirement of relatively precise roll alignment of the round in the tube due to the necessity to keep the FTP nose lift in the vertical plane. This would require a design to key the FTP to the round, which in turn would be keyed to the launcher.

- MIRADCOM inertial experts feel the Navy cost estimate of $5-$6 per FTP unit in large quantities is at least an order of magnitude too low. That is, MIRADCOM feels the cost of FTP will be in the $50-$100 range in large quantities.

- The Navy weight estimate of 0.2 lb was considered too low by the MIRADCOM evaluation team. It was felt that 0.5 lb for the entire retrofit FTP fixture, particularly with a hot gas type of gyro spinup, was much more realistic.

Preliminary MIRADCOM simulation studies indicate the FTP concept is feasible. As seen in *Figure 1*, the conventional M72 LAW can achieve excellent vertical plane miss at any given range, *i.e.*, 200 meters, if the desired range is known exactly and if the proper super elevation (raised sights) is utilized. However, for the 200m case, if there is error in the range estimate, *i.e.*, ±20%, the miss can be considerable, as much as 6-7 ft for the 200m case. When a properly sized FTP nose lifting device is attached to the M72 LAW, the trajectory is essentially flat (less than 1 ft) out to 200 meters, as shown in *Figure 1*. The sensitivity to range estimation errors is minimal, with vertical miss less than or equal to ±1 ft for ±20% variations in the 200 meter range estimate.

It is obvious from *Figure 1* that at least ideally, the FTP attachment can release launch personnel from the requirement to accurately estimate range. However, sensitivity of the FTP to system parameter variations appearing from round to round may be severe, negating any theoretical gains. *Figure 2* shows the sensitivity of vertical displacement of an FTP equipped M72 LAW to variations in launch velocity. It is seen from the figure that a relatively small perturbation in launch velocity (± 5%) from the nominal 450 ft/sec value results in ~ 5 ft miss. *Figure 3* shows the extreme sensitivity of the miss to the FTP lifting surface diameter. This indicates extensive wind tunnel testing to choose the proper nose diameter (and pitch) to provide just the right amount of lift to cancel gravity drop. Additional simulation runs show a sensitivity to misalignment of the FTP lifting vector with the vertical plane. A misalignment as little as 5° produces in excess of one foot deflection in the lateral plane.

4. FLIGHT TEST EVALUATION

A MIRADCOM in-house ten round flight demonstration program cost and schedule plan was developed and is presented in *Figure 4*. Approximately nine months after go-ahead, range testing of the hardware is scheduled to begin with final tests to be completed after fifteen months at a total cost of $380,000.

5. CONCLUSIONS

The basic FTP concept is feasible. However, independent MIRADCOM estimates of hardware costs make low cost FTP highly suspect. The FTP is sensitive to a variety of parameter variations, including launch velocity, initial misalignment of the lifting surface from the vertical, and nose diameter and pitch. A complete extensive simulation parameter variation analysis, wind tunnel modeling, and flight demonstration would be required to adequately prove the concept performance-wise.

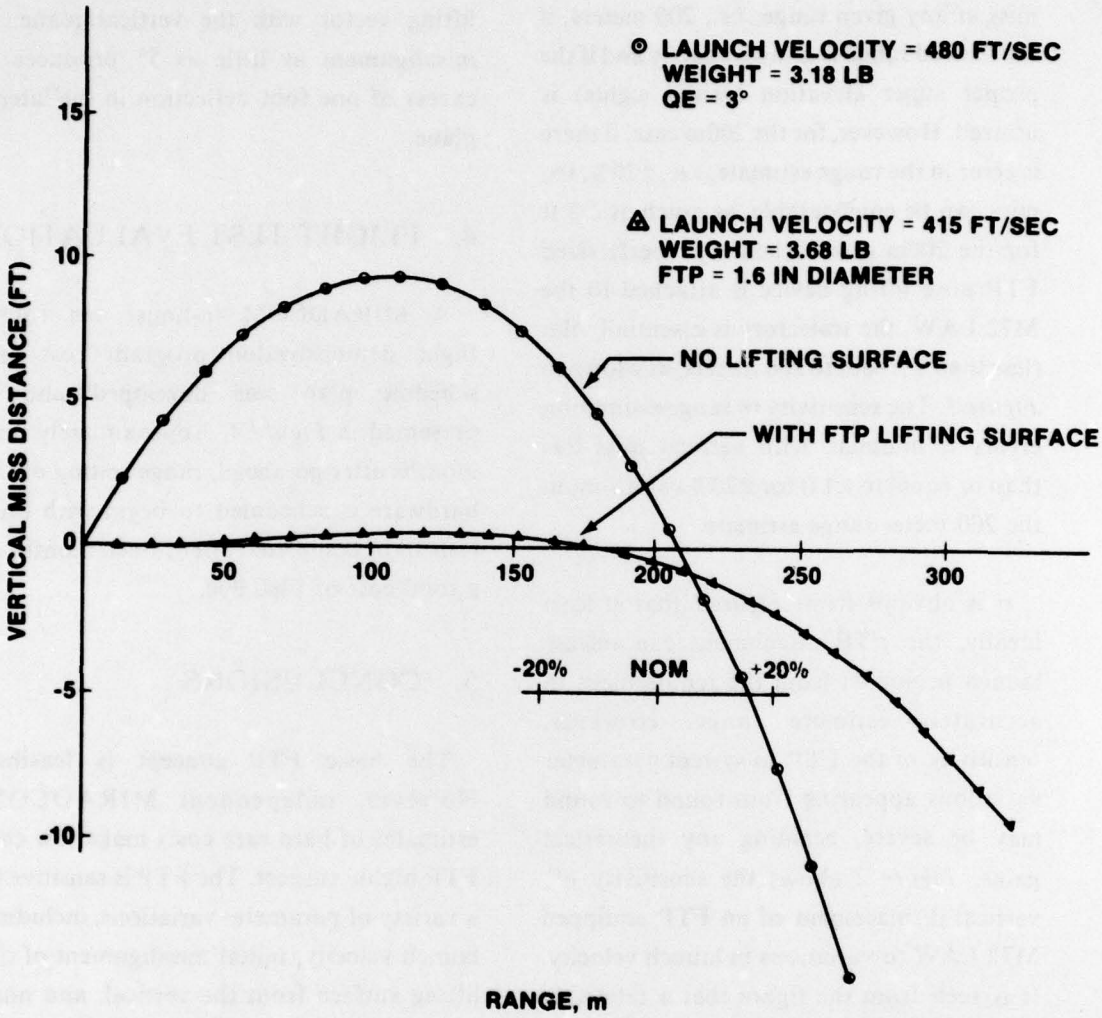

Figure 1. Vertical accuracy versus range for M72 LAW type projectile with and without FTP lifting surface.

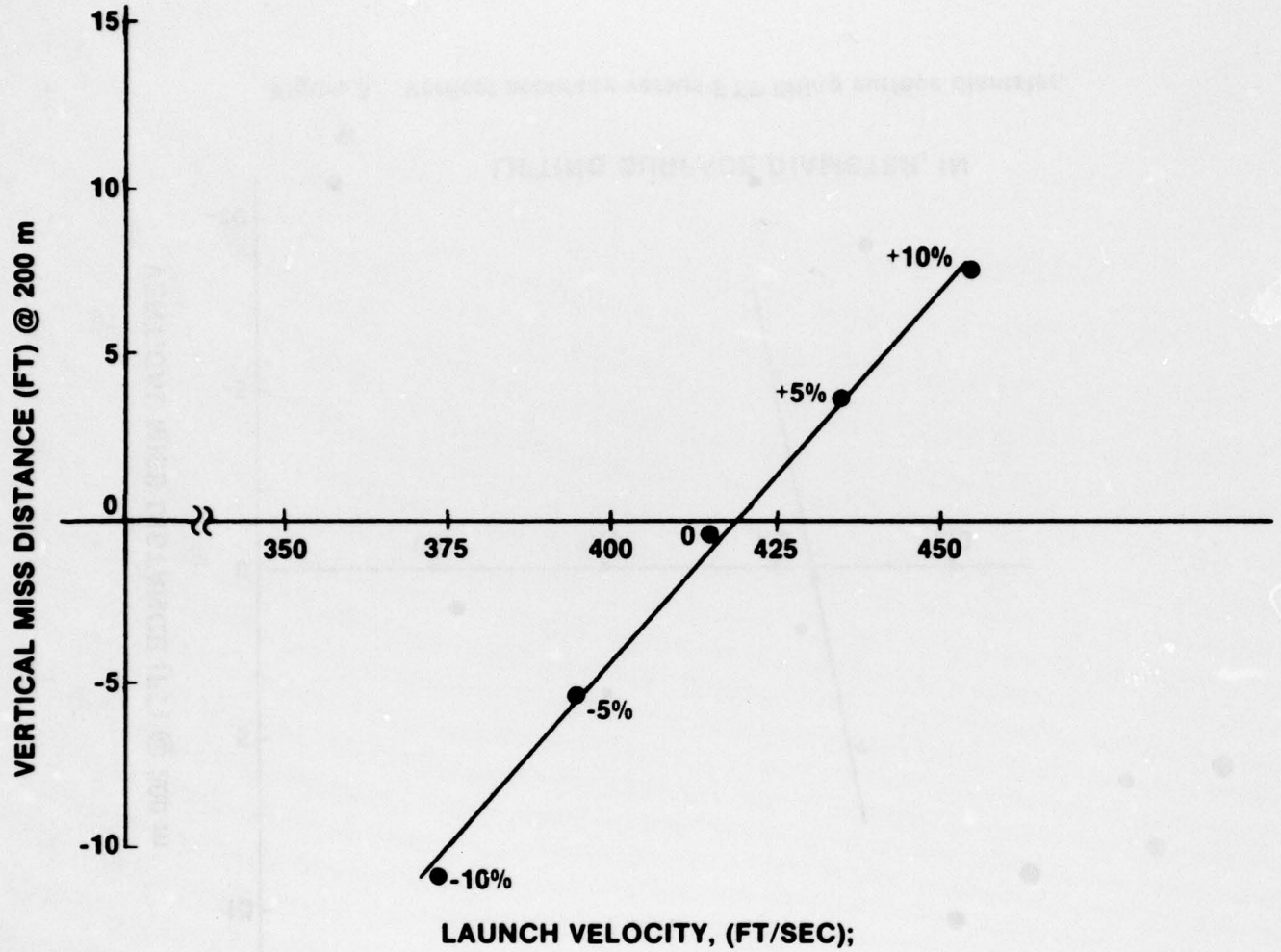

Figure 2. Vertical miss distance versus launch velocity for M72 LAW type projectile with FTP lifting surface.

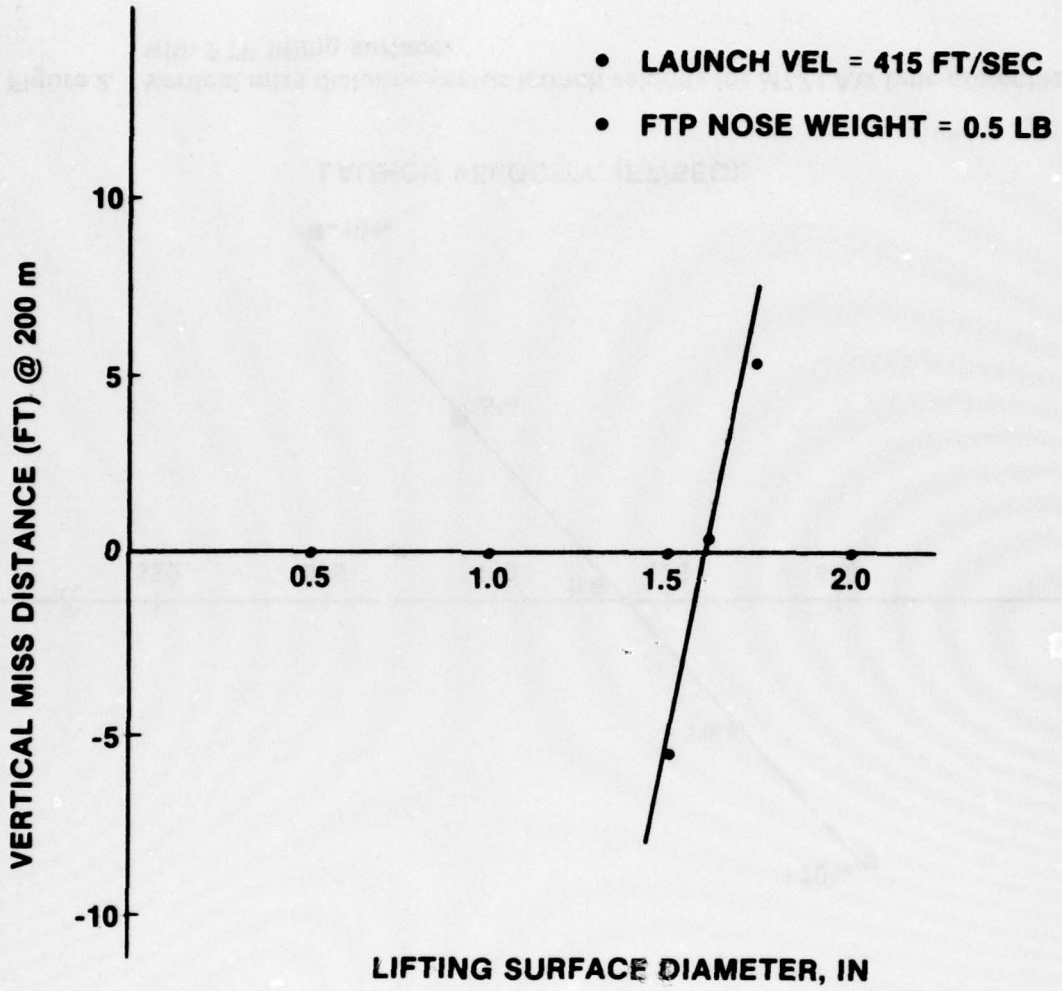

Figure 3. Vertical accuracy versus FTP lifting surface diameter.

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COST AND SCHEDULE: FLAT TRAJECTORY DEVICE

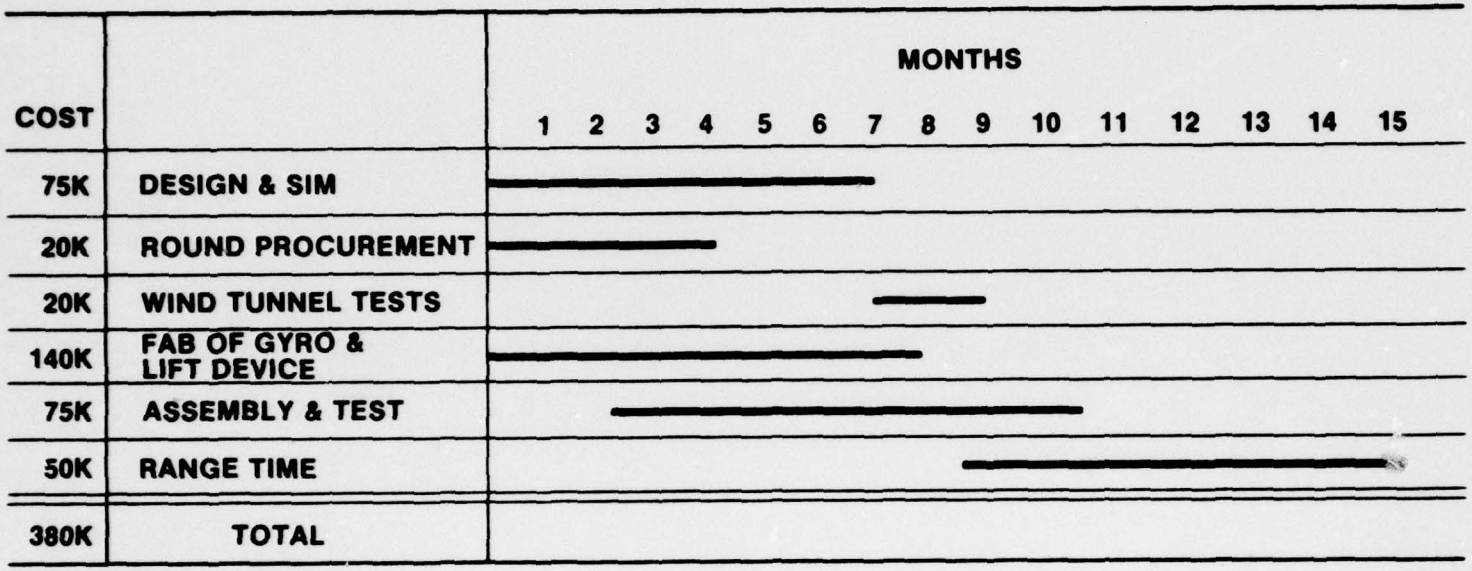


Figure 4. Ten round flight test cost and schedule.

APPENDIX A

THE NAVAL SURFACE WEAPONS CENTER (NAVSURFWPNCEN) FLAT TRAJECTORY PROJECTILE (FTP)

FLAT TRAJECTORY PROJECTILE (FTP)

REQUIREMENT

One of the highest priorities of USMC, U.S. Army and NATO land forces is the requirement for an effective light assault weapon for use against tanks, armored vehicles, bunkers, etc., and for use in urban warfare. For these applications direct fire (unguided) weapons have some advantages over guided weapons; the primary advantages are:

- simplicity of operation
- small, lightweight
- low cost
- invulnerable to distraction by smoke, heat, etc., which can impair the effectiveness of IR seekers or laser designated seekers.

The primary disadvantage of a direct fire assault weapon is that, because of the relatively low projectile velocity, the launcher must be elevated to compensate for gravity drop. Gravity drop is a function of flight time; the slower the projectile, the higher the launcher angle required to range information or estimation. According to the Army training manual for the 60 mm mortar M-19, FM 23-85, "Eye estimation by untrained men is little better than a guess and the average error of such men is at least 20% of the range." The vertical error that results from a 30% range estimation error, at a range of 250 meters, is shown in *Figure A1* as a function of launch velocity. It can be seen that for a launch velocity of 480 FPS (M72 LAW launch velocity) the resulting vertical error is 18 feet. For a launch velocity of 800 FPS the vertical error resulting from a 30% range estimation is 7 feet. In order to reduce the vertical error below 7 feet, the range estimation error must be considerably less than 30% or the launch velocity must be higher than 800 FPS.

Figure A2 shows vertical error as a function of range for a 30% range estimation error. It is apparent that in order for direct fire weapons to be effective at ranges beyond 250 meters, accurate range estimation is critical. In order to estimate range with useful accuracy requires:

- extensive training
- time, concentration and mental dexterity at the time of estimation.

Under some conditions and against some targets a stadiametric sight will ease both of these requirements. However, when the target is moving and changing aspect or when the target is different from the target for which the sight is calibrated or when the target is mostly obscured by darkness, smoke, dust, etc., the usefulness of the stadiametric sight is seriously compromised.

At the request of the Firepower Division of the Marine Corps Development and

Education Center (MCDEC), the Naval Surface Weapons Center (NAVSURFWPNCEN) had developed a concept whereby a projectile can be made to fly a flat trajectory, thereby eliminating the need for adjusting the launcher to compensate for range and, of course, eliminating the need for estimating range. The primary advantages provided by this capability are that the need for extensive training is alleviated and more importantly, that the additional battle stress imposed by the requirement that the operator make a judgment that is critical to the effectiveness of his weapon is alleviated. Other advantages provided by the FTP concept are improvement in vertical accuracy (vertical accuracy comparable to no error in range estimation) and that the FTP can be used in situations where there is a clear line-of-sight to the target but where overhanging obstructions, such as tree branches, might entangle a projectile on an elevated ballistic path. In addition, the FTP concept provides the potential for extending the range at which a shoulder fired assault weapon can be effective and also provides an alternative to higher launch velocity for reducing the dependence upon accurate estimation of range.

OPERATIONAL CONCEPT

The NAVSURFWPNCEN approach for enabling a projectile to fly a flat trajectory is to balance the force of gravity by configuring the projectile to develop aerodynamic lift equal to its weight. This is accomplished by pitching the projectile to an angle of attack at which the body aerodynamic lift equals the projectile weight. This in itself is not a particularly difficult task. The challenge is in keeping the aerodynamic lift vector oriented in the gravity plane. *Studies show that if the lift vector is rolled as much as five degrees out of the plane of gravity, the resulting component of force in the lateral plane will cause an unacceptable deflection error.* In order to prevent this, the pitching moment which rotates the body to an angle of attack is developed by an asymmetrical nose ramp which is roll stabilized in the gravity plane. Thus, assuming the projectile body is symmetrical, as long as the pitching moment is aligned with the gravity plane, the lift vector will also maintain alignment in the gravity plane. By uncoupling the body from the nose ramp by a roll bearing, the body can rotate freely without changing the direction of the lift vector. Roll stabilization of the asymmetrical nose ramp is provided by a small, one gimble gyro.

DESIGN CONCEPT

A mechanism for providing the aerodynamic moment, for housing the gyro wheel and gimble and for spin-up of the gyro can best be optimized by integrating these components and functions into the projectile design. However, one objective for the NAVSURFWPNCEN design concept was to provide FTP capability without impacting the design of the projectile on which it would be used. This, of

course, also allows a retrofit capability. Accordingly, the present concept is for all the FTP mechanism to be contained within an adapter as shown in *Figure A3* which can be mounted on the nose of a projectile. At the front of the adapter is the aerodynamic ramp for providing the required pitching moment. The gyro and gimble for roll stabilizing the ramp are mounted inside of the ramp. The concept for gyro spin-up is a set-back weight attached to a fine wire wrapped around the gyro wheel which, upon launch set-back, will spin-up the gyro to approximately 300 Hz. Even with inexpensive, relatively high friction bearings, this spin rate is sufficient to provide several seconds of roll stabilization of the nose.

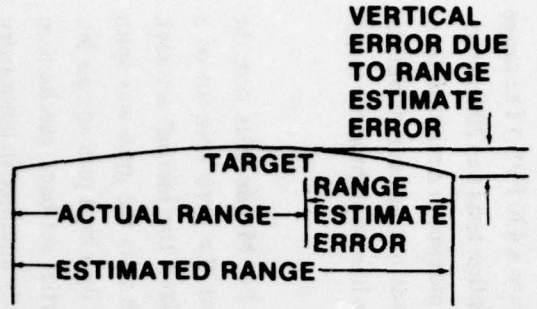
STATUS

The FTP concept has been demonstrated to be feasible. Three special test vehicles incorporating the concept were fabricated and successfully tested at Ft. Meade, Maryland. Over a distance of 220 meters, the maximum observed vertical deviation from the line-of-sight was approximately six inches (after correction for small error in launch velocity); and the maximum deflection error was within the expected random dispersion. The nominal launch velocity of all three of these vehicles was 800 FPS.

Subsequent to the demonstration of concept feasibility, a demonstration was conducted to show compatibility of the concept with a typical weapon configuration. For this demonstration an M72 LAW configuration was modified to incorporate the FTP concept, as shown in *Figure A4*. Two such vehicles were successfully demonstrated in tests conducted at the USMC Base, Quantico, Virginia. The launch velocity for these tests was nominally 430 FPS. (Launch velocity of the M72 is 480 FPS. With the additional weight allocated to the FTP device, 0.20 lb., the resulting velocity is 430 FPS.) The range of these demonstration tests was 200 meters. In these tests the maximum deviation from the line-of-sight was not measured, but the deviation from the line-of-sight at the target was 11 inches.

In neither the Ft. Meade tests nor the Quantico tests was the gyro spin-up of a design which utilized the inertial set-back technique. In both tests the gyro was spun up prior to launch by a high pressure air jet. Although the inertial set-back mechanism has been successfully operated in laboratory tests, it has yet to be demonstrated in actual flight tests.

It has been estimated that the FTP retrofit device can be designed to weigh only 0.2 lb and to be mass produced for approximately five dollars each.



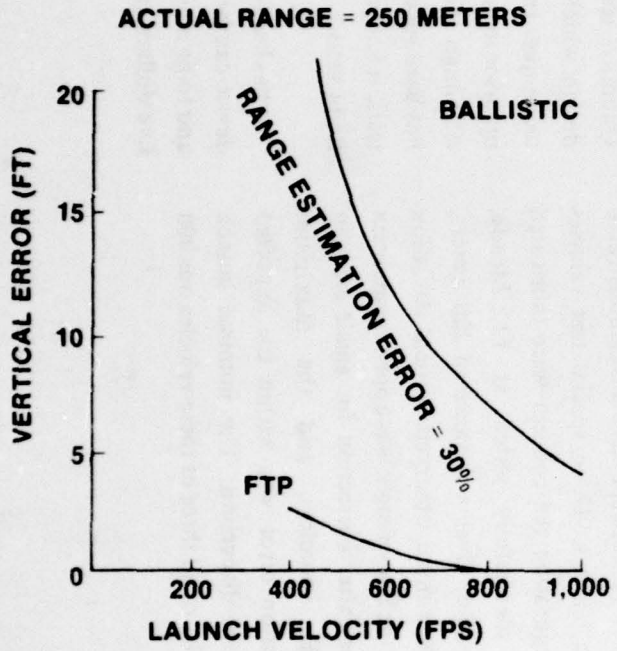


Figure A-1. Vertical error versus launch velocity.

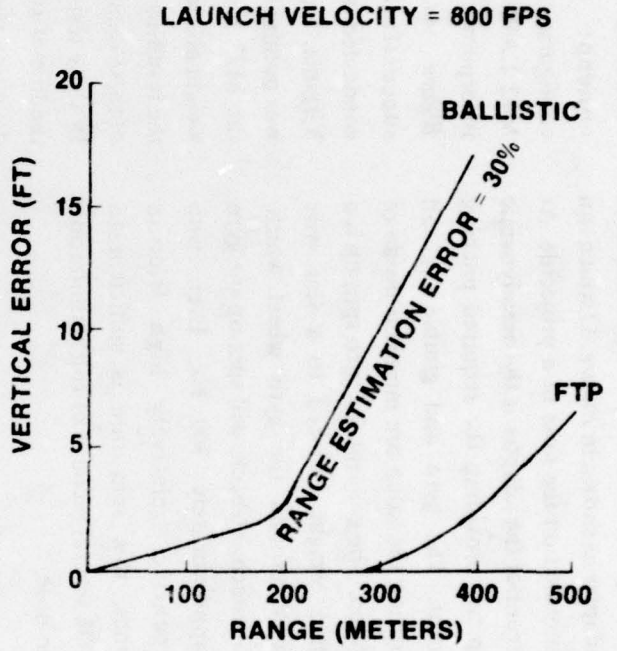
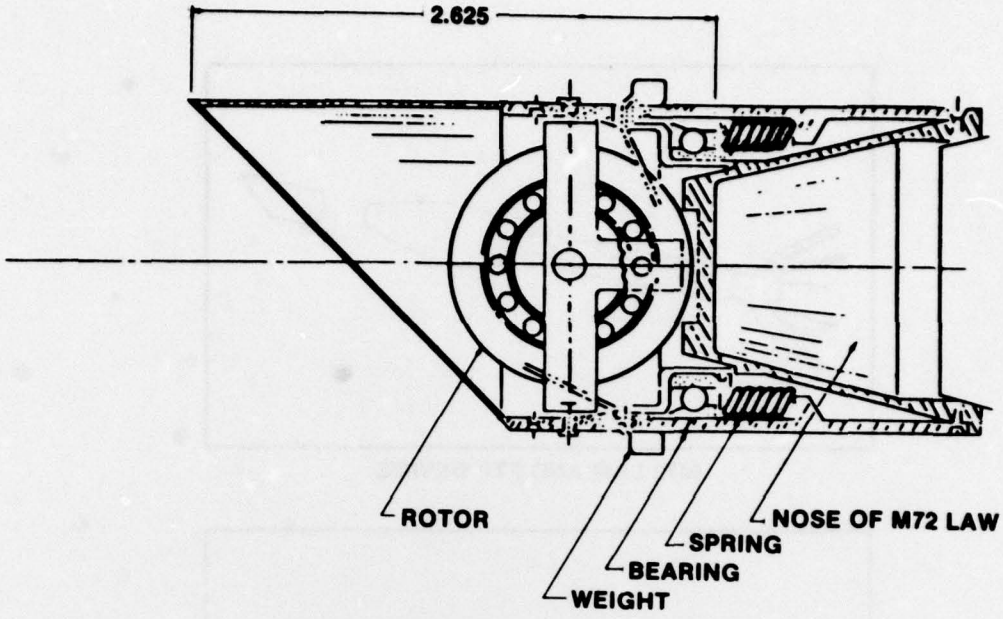


Figure A-2. Vertical error versus range.



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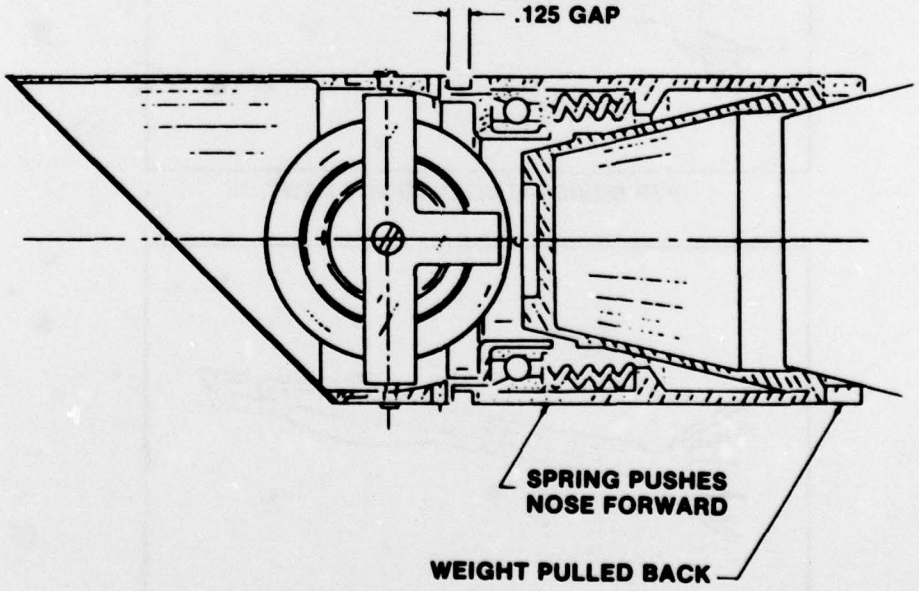
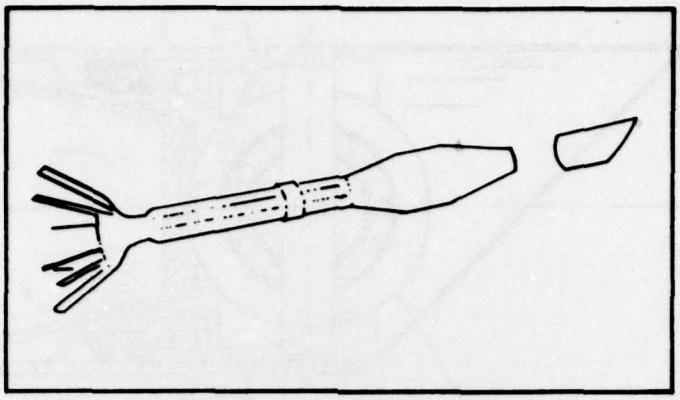
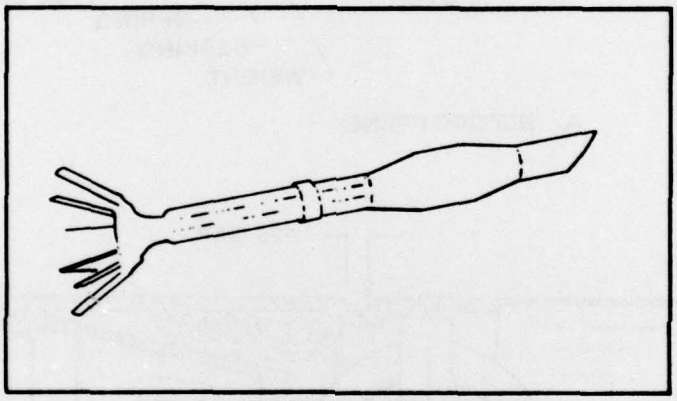


B. AFTER FIRING

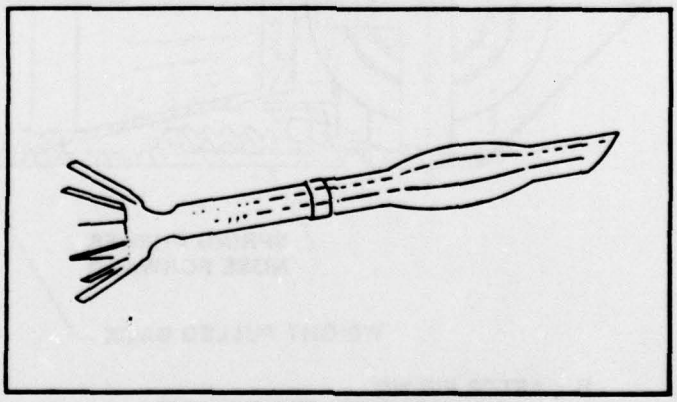
Figure A-3. FTP design concept.



M72 LAW AND FTP DEVICE



FTP DEVICE MATED TO M72 LAW



M72 LAW/FTP TEST VEHICLE

Figure A-4. Adaptation of FTP to M72 LAW.

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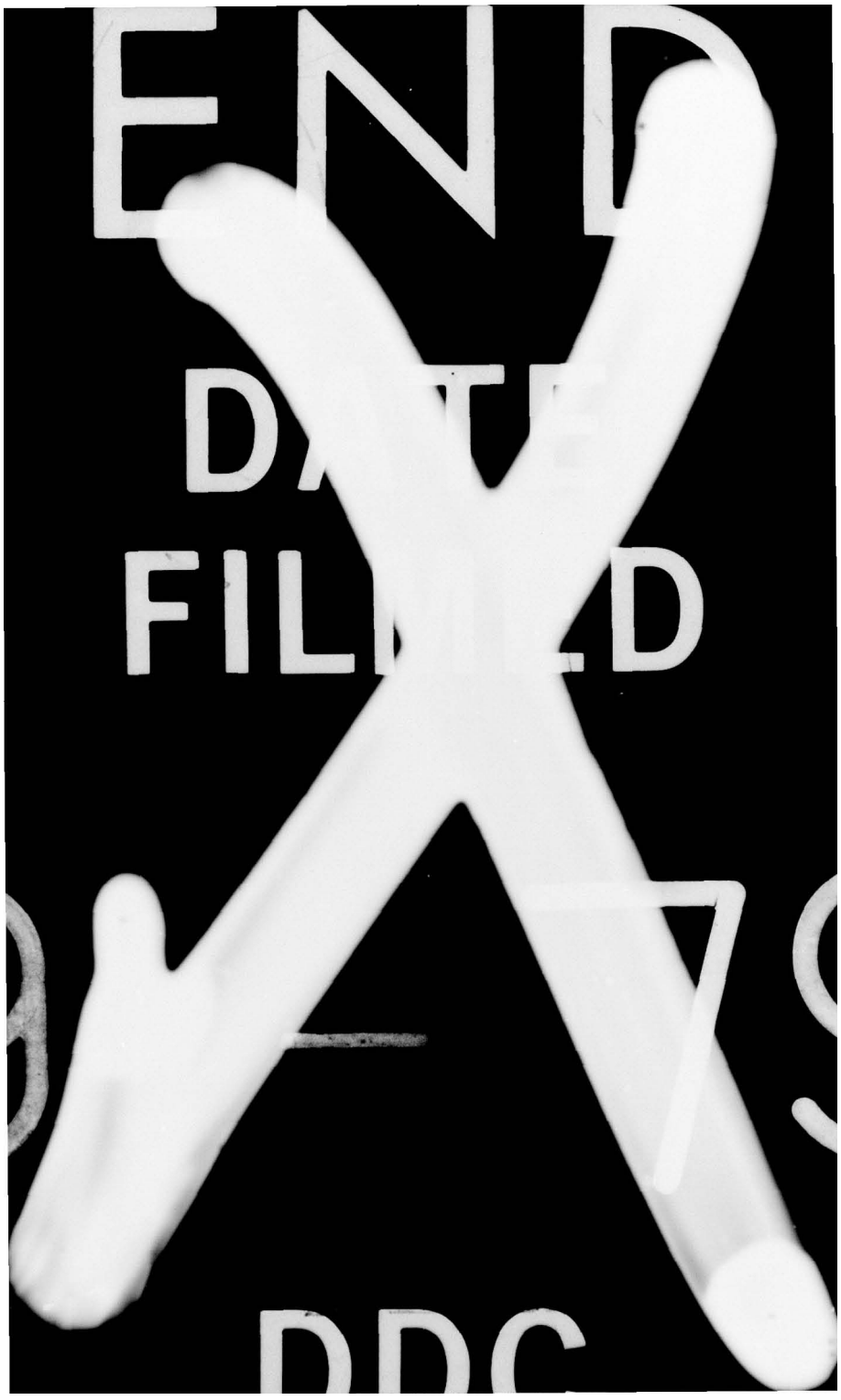
-TI (Reference Copy)	1
-TI (Record Set)	1
-TK, Dr. Rhoades	1
-TK, Mr. Connaughton	1
-TL, Mr. Lewis	1
-TN, Mr. Dobbins	1
-TE, Mr. Lindberg	1
-TEO, Mr. Widenhofer	1
-TR, Mr. Bates	1
-TRT, Dr. Hartman	1
-ET, Mr. Black	1
-ETP, Mr. Northrop	1
-ETP, Mr. Wahlheim	1
-ETP, Mr. Presson	1
-ETR, Mr. Priddy	1
-ETR, Mr. Crocker	1
-ETR, Mr. Aufderhar	1
-TFG, Mr. Fowler	1
-YOR, Mr. May	1
DRDMI-V, MAJ Love	1
-DRDMI-V, Mr. Leeper	1
-TRADOC Liaison Office	1
-US Marine Corps Liaison Office	1
DRSMI-LP, Mr. Voigt	1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AD-A073 317 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 19/4
PRELIMINARY EVALUATION OF THE FLAT TRAJECTORY PROJECTILE (FTP) --ETC(U)
MAY 79 C L LEWIS

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SUPPLEMENTARY

INFORMATION

MC

DEPARTMENT OF THE ARMY
UNITED STATES ARMY MISSILE COMMAND
REDSTONE ARSENAL, ALABAMA 35809

DRSMI-RPT 29 Nov 79

SUBJECT: Technical Report T-79-51, (Preliminary Evaluation of the Flat Trajectory Projectile (FTP) Concept)

TO: All Recepients of Subject Report

DD Form 1473 of subject report contains errors in blocks 9 and 20. The following pin and ink changes should be made; change block 9 office symbol to read DRDMI-TG, and second sentence of block 20 to read, "This unit would attach to a projectile without altering the design, and thus would comprise a simple retrofit".

John W. Chambers

JOHN W. CHAMBERS
C, Technical Information Division
Laboratory Support Office
US Army Missile Laboratory