A DYNAMIC SIMULATOR FOR TRAINING WITH MAN-PORTABLE AIR DEFENSE WEAPONS

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INTRODUCTION

The depth of training required for weapon systems that have a high man-engagement performance requirement is a difficult task.

Should a man solely depended upon to engage and destroy a high-performance/high-value threat be allowed to train by actually firing the weapon? When the gunners number in the thousands and the weapon costs in the thousands, would this be practical? Conversely, can the gunner realistically be totally trained without experiencing a live weapon firing? Even the USA and USMC differ in their solutions to this dilemma as evidenced by their individual approaches to training for the Redeye weapon. Hopefully, both services will realize that for the new Stinger weapon the common goal must be a well-trained, confident gunner.

Both the Redeye man-portable air defense weapon and its upgraded version, designated Stinger, are designed so that one man can shoulder-launch the missile to intercept and destroy threats ranging from hovering helicopters to high-speed maneuvering jet aircraft threats.

The necessity for having a well-trained gunner that can engage a high-value threat on the first attempt requires a high degree of weapon confidence and operational proficiency. Brunswick Corporation as the prime contractor for the USMC to develop a Redeye Launch Simulator (RELS) and a Stinger Launch Simulator (STLS) believes the answer lies in providing a trainer that allows a cost-effective live firing experience. This training of a new student or requalification of a trained gunner can be effectively culminated by firing a low-cost duplication of the actual weapon.

TRAINING NEED

The Stinger Weapon System's introduction into our arsenal of air defense weapons creates a unique training requirement. It is a man-portable air defense weapon that can engage all types of threat aircraft from hovering helicopters to high-speed maneuvering jets. Different than its predecessor, Redeye, the Stinger has an all-aspect engagement capability.

Stinger is an extremely effective weapon in the hands of a well-trained, skilled, and confident gunner. How do we attain this well-trained, skilled and confident gunner? The ideal method would be to provide the gunner with an adequate number of Stingers and allow him to fire at targets representative of the threat until he becomes proficient, and confident in his weapon's capabilities, and of course to provide additional Stingers periodically so he could maintain his proficiency. Once the gunner has attained proficiency and established confidence, he can then concentrate on the other combat skills required to become totally effective.

Mission impossible? Only partly. The Stinger Weapon System costs in excess of $30,000 each and the costs associated with developing and using representative targets are astronomical.

How then can we hope to train a Stinger gunner? Weapons system simulation is the answer, and not just simulation, total gunner related weapons simulation.

The Stinger Launch Simulator (STLS) provides total weapon system simulation due to the requirement that the gunner perform the required prelaunch functions which allows the simulator to function exactly like the Stinger weapon, through the launch of an eject only missile. This provides the gunner with a dynamic simulation of weapon system performance while under pressure of an incoming aircraft as depicted in Figure 1.

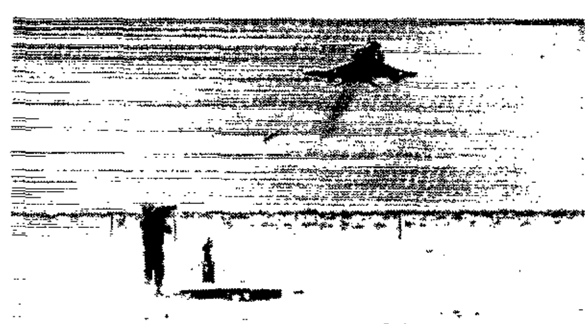


Figure 1. STLS Live Firing

Stinger is a fire and forget weapon and so is the STLS. Once the Stinger exits the launch tube the gunners participation in the engagement has ended. STLS takes the gunner through all of the prelaunch steps and launch sensations which are identical to Stinger. The only steps in the Stinger engagement sequence that STLS does not simulate is missile flight and intercept.

The STLS gunner experiences everything he would with the Stinger except for the thrill of the kill. Additionally, he is required to handle the STLS as he would a Stinger in regard to safety. STLS will indeed fill the need for a training device that will build confidence and increase proficiency while keeping training costs low.

SIMULATOR CONCEPT

The STLS concept is based on maximum duplication of weapon design and usage characteristics. Identifying features of the two systems shown in Figures 2 and 3 are difficult to distinguish, yet one is a $30,000 weapon, the other a $350 simulator.

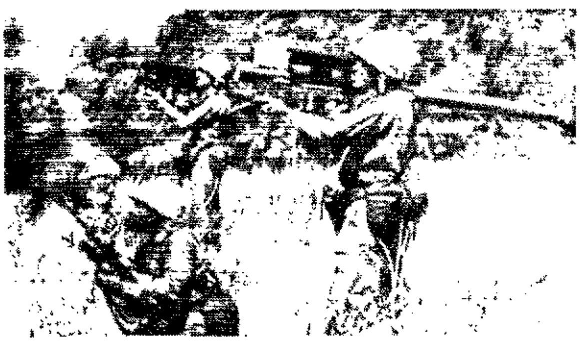


Figure 2. Stinger Weapon

There exists four **major** subsets of the basic simulator including launcher, eject motor, eject missile and support items. Each of these were given special attention in terms of design criteria to maintain maximum representation of the weapon at minimum cost.

LAUNCHER - The launcher is basically an expended Stinger Launcher modified to launch eject missiles on a recurring basis. This entails mounting the IR seeker, normally expended with the weapon, to the launcher allowing extensive reuse. An electronic module is added to the reusable gripstock to provide the interface electronics normally associated with the weapon missile. Additional minor items such as a retainer screw and igniter interface have been changed to permit extended reuse.

Since the standard launch tube is normally expended after each firing, a protective shroud is added to the motor. This allows a minimum of 100 firings before the relatively low cost tube must be replaced. The higher cost-items such as the seeker, gripstock and electronic module are easily added to a new launch tube.

Figure 3. Stinger Launch Simulator

EJECT MOTOR - The eject motor is the heart of the expendable part of the system. Conceptually the approach is to maintain a man rating level of safety while incorporating as many value engineering features as possible. An example is the weight sensitivity of the weapon boost motor forcing use of a high-strength, low-weight 300 Maraging Steel case which is also high cost. With STLS where weight is not critical, an extra thick 4130 steel case is utilized.

Cost reduction designs have also been implemented on the nozzle assembly, propellant retainer cap and eject missile interface hardware. All performance characteristics such as pressure, total impulse, burn time, etc., have been retained so that the launcher eject phase of the flight is identical to the weapon.

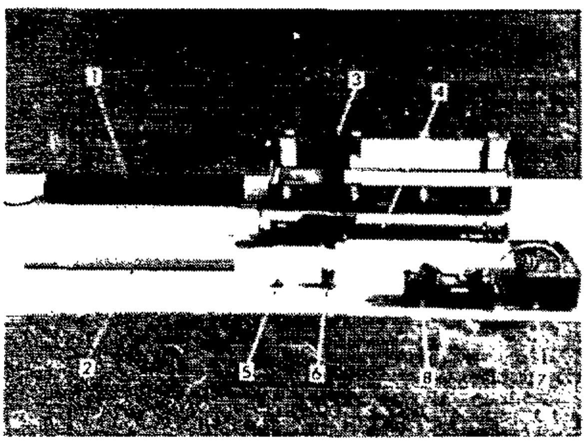
EJECT MISSILE - The eject missile consists of the man rated, low-cost eject motor attached to a ballasted forward section. Conceptually the eject missile has a total weight identical to the weapon in order to ensure that the eject parameters remain identical. Low-cost production techniques have resulted in an aluminum extruded section cut to length, threaded and machined at the motor interface and edges chamfered on the front end. When assembled to the motor it is packaged in a missile container allowing ready removal and subsequent simple insertion into the launch tube.

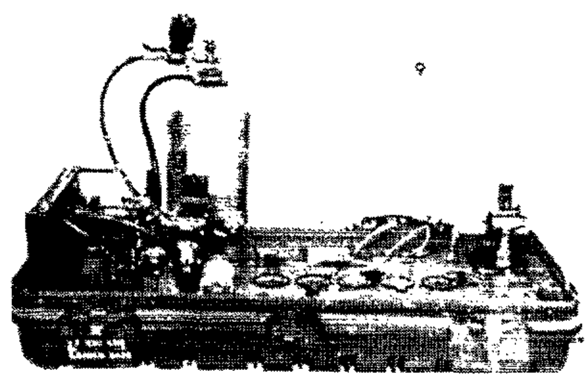
SUPPORT ITEMS - In the earlier RELS development program little attention was placed on support items resulting in significant recurring costs associated with these items. Realizing the potential quantities associated with STLS training, a new approach was taken. Instead of utilizing an expendable tactical Battery Coolant Unit (BCU), a trainer battery coupled with a gas bottle was selected. Launcher design was established such that the bottle could be easily installed just prior to firing. Although initially conceived as a single shot device for simplicity, an option for a multishot gas supply has been developed. Thus the per firing costs for support items can be reduced to the point where the only significant recurring cost is associated with the eject missile.

With the established conceptual approach of maximum weapon duplication at minimum recurring cost, design definition to ensure compliance was initiated. All lessons learned on a predecessor program (RELS) coupled with response to the defined training need were established as design criteria.

DESIGN APPROACH

To ensure full system value, the design approach to the STLS consists of a total training package. The package, including all support items, is shown in Figure 4.





1. Eject Missile Container
2. Eject Missile
3. Launcher Container
4. Launcher
5. Gas Bottle
6. Trainer Battery
7. Battery Charger
8. Battery Charger Receptacle
9. Redeye Test Set Modified for STLS

Figure 4. STLS Training System

In addition to the key criteria of maximum weapon similarity at minimum recurring cost, a number of key design factors were established including:

- Deliver a fully assembled eject missile to minimize handling and safety as related to the trainee.
- Maximize the number of eject missiles in each disposable container yet stay within human engineering limits.
- Package all items except the eject missile in the launcher container so that the required gas supply and battery power are readily available in the quantities needed.
- Ensure the gas bottle design (6000 psi Argon) is safe during shipment as well as if there is a post installation mission abort.
- Perform extensive tests to verify eject motor changes so no compromise to man rating factors exist.
- All man/simulator interfaces will remain unchanged to preclude any differences between simulator and weapon.
- Stress commonality of simulator with existing weapon support equipment.

As illustrated in Figure 4, the design approach for the various subsystems can be highlighted as follows.

1. EJECT MISSILE CONTAINER - A picture of the container with one eject missile partly extended is shown in Figure 5. The container is an off the shelf government approved container that is low cost, readily available and can house up to three eject missiles. Plans are to make the container expendable to preclude logistic problems. Dunnage is provided on the ends and center for support and simple clamped ends are provided for retention. Design considerations utilized human engineering limits.

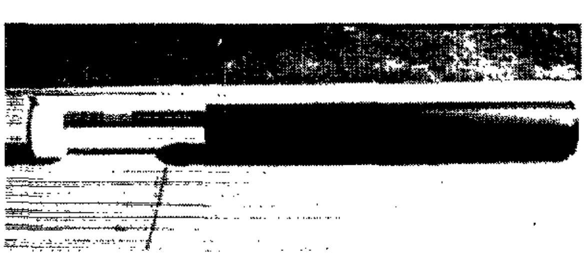


Figure 5. Eject Missile Container

2. EJECT MISSILE - The eject missile is illustrated in Figures 6 and 7 as the forward section and eject motor respectively. Mating of the two units form the assembled eject missile.

The eject missile forward section is a simple aluminum extrusion groved and cut off to provide an identical weight to Stinger. Minimal manhours to finish the forward and aft sections by machine have been included. An alodine coating is applied for long-term exposure protection. A key factor is to maintain a precise alignment between the eject motor and forward section and to minimize costs. It currently is an expendable item, but value engineering studies may determine that reuse is cost-effective.

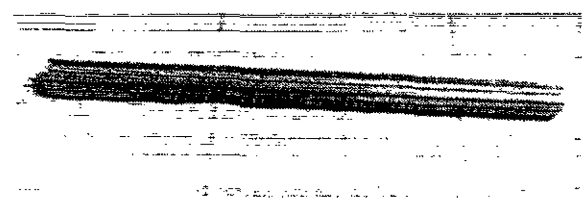


Figure 6. Forward Section

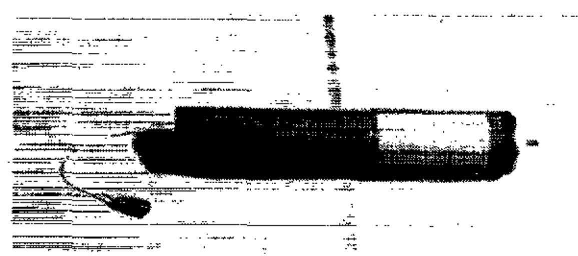


Figure 7. Eject Motor

The eject motor is the key component in the areas of cost and safety. A fine balance must be achieved between low cost and retention of man rated safety levels. A deviation from Stinger was included only in the areas of motor case thickness and material, nozzle design and boost/sustain separation interfaces. No change to the internal combustion chamber design, propellant design or squib design was allowed. A minimal firing test program to verify all changes is in process. In areas of change, high safety factors were established to allow cost-effective design where no weight sensitivity exists. An integral blast shroud was added to the motor to prevent exhaust impingement on the launch tube. This is needed to ensure a minimum of 100 firings from each launch tube. Also shown is the squib lead with connector which mates to the launcher. Care to ensure proper EMI protection on heavily instrumented ranges was also considered.

3. LAUNCHER CONTAINER - The launcher container shown in Figure 8 houses the launcher, 3 trainer batteries and 45 gas bottles.

Figure 8. Launcher Container

Modification to the dunnage of the Stinger qualified container is all that is required for this container. Thus all the key launch hardware, except the eject missile, is provided in a single reusable container.

4. LAUNCHER - The modified GFE Stinger launcher with gripstock is shown in Figure 9. Only the forward mounted seeker provides visual identification of differences between a STLS and a Stinger launcher. Additional interface modifications including the electronic module, solenoid valve, coolant passage, gas bottle receptacle, torque screw retainer and connector interface are needed for the system to function but are not evident to the trainee. All modifications are kept from interfering with the gunner's normal handling of Stinger. Thus the changes are either in the forward area, inside the gripstock or behind the gunner's shoulder.

Figure 9. STLS Launcher

To protect overall cost effectiveness, the hardware attached to the launch tube was minimized since it is discarded sometime after 100 launches. The remaining parts can be reused with a new launch tube.

The electronic module, tightly packaged in the gripstock, provides the electronic signals normally associated with the missile. These include a time delay, igniter pulse tailoring, tone cutoff and solenoid valve activation. Printed circuit boards within the module are replaceable items.

5. SUPPORT ITEMS - A number of support items exist which include the gas bottle trainer battery, battery charger and battery charger receptacle.

The gas bottle is the major new designed piece of equipment compared to the previously successful RELS. To allow use of the GFE trainer battery, a source of Argon gas to cool the seeker is required. The ultimate design considered cost, safety and installation human engineering factors. For cost effectiveness, a standard TOW qualified bottle was modified for STLS including safety factors of 2 times MEOP as proof pressure. The volume of 2 in^3 was derived from Stinger data. Remaining to be defined was the bottle to launcher interface which had to include an automatic means of bottle opening, venting considerations and removal problems. The final configuration allows safe installation within human engineering allowable torque limits, noninterference with gunner functions, safety to the gunner and a positive venting system for removal. Drop tests were also performed to ensure handling safety.

The trainer battery charger and receptacle are all GFE items and have proven their usability in previous field training activities. This equipment allows reusability of the battery at the field unit support level.

6. TEST EQUIPMENT - The non-exacting requirements for STLS permitted imagination in defining the test and checkout equipment. Rather than specify a high cost Stinger test set for STLS, Brunswick opted to upgrade the Redeye/RELS test set to be compatible with STLS. Additions for different seeker sensitivity, IFF and gas supply were the prime changes required. These have been successfully completed on the initial unit thereby saving the Stinger training program thousands of dollars. Similar modifications can be performed on additional test sets at approximately 15% of the cost of building a Stinger test set.

TRAINING APPROACH

The Stinger gunner must be capable of engaging and destroying all types of low-altitude aircraft from helicopters to high-performance jets. To accomplish this, the gunner must be highly proficient in numerous mental and physical skills with consistent performance capability. The operational proficiency and consistent performance must be achieved in the Stinger training program. The gunners performance reliability is attained by instilling confidence in his operational abilities and the systems capabilities to intercept and destroy threat aircraft.

The training program for Stinger gunners is similar to the current Redeye training program. This begins with a four-week school at the U.S. Army Air Defense School, Fort Bliss, Texas. The subjects covered include weapons system capabilities, aircraft recognition, range ring profiles, map reading, tactical employment and system trainers. Due to the peculiar mission of Stinger, many hours are devoted to the use of trainers and the Stinger Launch Simulator. The trainers currently being utilized are the Field Handling Trainer (FHT) and the Tracking Head Trainer (THT). The FHT is an expended launcher which has been ballasted to simulate the weight and balance of the tactical weapon. It is used for familiarization and reaction drills and has no functional parts. The THT is a full-size model similar to the actual weapon and provides all functions of the weapon except missile launch. It is used primarily for tracking, target acquisition and ranging.

The Stinger Launch Simulator (STLS) is the link between the trainers and the weapons system. It provides a low-cost, highly representative firing system which simulates all aspects of the Stinger firing through the launch motor firing and ejection of the training round. The STLS provides the means for training and establishing performance proficiency of the Stinger gunners in the handling, operation and firing characteristics of the weapon. The STLS duplicates the Stinger weapon through all operational phases including activation, acquisition, time delays, initial launch characteristics such as launch motor ignition, recoil, over pressures, backblast and weight loss on missile launch. STLS provides complete weapons system simulation with the exception of sustained missile flight and intercept, thereby simulating everything that the gunner has any control over.

The STLS primary role in the training structure is to build confidence. Its secondary role is as a handling and a weapon familiarization trainer. STLS may play an even more important role for the Stinger system than RELS did for Redeye. STLS may be the one firing experience that the gunners will have because of the high cost of Stinger. While all Marine Redeye gunners fired a Redeye upon graduation and an annual required round, this will not be possible with Stinger. Thus one of the most important training experiences, actual weapon firing, is lost. The STLS has been developed to fill the void created by the loss of actual weapon firing. It will provide the Stinger gunner with a simulator that will take him through all of the prefire and fire events that he has any control over. Once the missile has been launched, it is out of the gunner's control. Therefore, to enable the Stinger Missile to hit the target, it is necessary to perform all of the steps leading up to missile launch correctly. Because of the low cost per firing, STLS will provide the gunner with the capability to refine his skills. The low cost per training round will also provide the capability for repeated firings, thus increasing the gunner's abilities. With the enhancement of his abilities comes confidence in himself and in his weapon. Because there is a certain element of fear involved in firing a weapon of this type from the shoulder, repeated firings of the actual weapon or an authentic simulator will alleviate this fear. Also, there is often a problem of handling this type of weapon after training with mockups or inerts. STLS requires the same type of handling as the Stinger weapon thus adding another benefit to its use.

Training for a weapon system such as Stinger should not be taken lightly. It is a system capable of destroying a sophisticated threat or one of our own aircraft. To ensure that the Stinger weapon eliminates the proper threat requires a well-trained confident gunner. STLS provides insurance that a skilled, confident gunner is in the field.

HUMAN FACTORS

The Man-Portable Air Defense Weapon Systems (MANPADS) are unique in that their operational effectiveness is totally dependent on the gunners performance. The individual gunner is responsible for the correct operation of the weapon and required engagement procedures and procedural sequence for specific types of aircraft. The gunner engagement requirements have created physiological and psychological performance standards which were beyond the documented state of the art. The high-performance standards are essential in order to engage and destroy contemporary and future low-flying, high-velocity tactical jet aircraft. The majority of existing low-flying attack aircraft have the capability of velocities from approximately 400 to over 600 knots. These speeds translate to 205 ⟶ 308 meters per second that the aircraft is penetrating the defended airspace. Therefore, the air defense gunner must perform his operations and engagement decisions in a very few seconds.

The engagement procedures are extensive and require rapid decisions and motor skills on the part of the gunner. The major engagement tasks are shown in Figure 10.

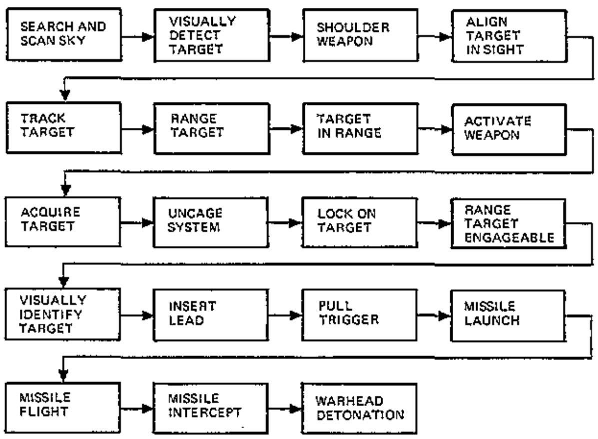


Figure 10. Engagement Procedure

The gunner tasks and control of the missile weapon system culminates with the missile launch. Once the missile is launched the internal navigational onboard system guides the weapon to the target.

The gunners training enables the individual to achieve a high standard of engagement performance. The gunners performance proficiency is continually upgraded, maintained and tested through (simulated) training programs. The one factor that is of major concern and often questioned is the gunners anxiety and reliability to actually fire a 2.75 inch missile from his shoulder. The gunner anxieties are created by the missile launch functions.

GUNNER ANXIETIES

The gunner anxieties are basically a fear of the unknown relative to the missile launch characteristics. The majority of air defense gunners have experienced firing rifles and other small arms prior to entering Redeye or Stinger weapon systems training. During rifle firing the gunner experiences a substantial recoil or "kick" and a high degree of noise. This previous experience conditions the man to be apprehensive about the firing characteristics of larger weapons. In addition, the gunners are exposed to motion picture films of Redeye and Stinger firings and also one actual demonstration firing during training. The actual firing is very impressive and also appears very awesome to the gunner spectators. The firing takes place in front of the spectators with the rear of the weapon pointed toward them. This situation amplifies the missile launch characteristics.

- Missile launch characteristics (spectator perception)

  Noise - is amplified as it is directed from the tube toward the spectators
  Flash - the motor ignition is a short flash of fire
  Recoil - the launch tube appears to jump on the gunners shoulder
  Debris - dust seems to surround the gunner
  Smoke - appears to envelop the gunner
  Launch - missile shoots from launcher on gunners shoulder and the sustainer motor ignites a short distance in front of gunner

The preceeding perceived firing characteristics are not representative of what a gunner actually encounters when firing a weapon from his shoulder.

When the weapon is on the gunners shoulder, he is totally protected from the missile launch characteristics. The noise, overpressures, flash, backblast, smoke and debris are directed behind the gunner. The recoil is approximately the same as firing a .22 caliber hornet rifle. The most noticeable sensation is the change of weight as the missile exits the launch tube. The actual firing characteristics are very stringent relative to the gunner.

- Firing conditions

  Noise (at gunners ear) - $\leq$168 db
  (25 db ear protection) - $\leq$143 db
  Recoil - $<$0.8 lb/sec
  Overpressure - $<$3.0 lbs per sq in
  Backblast - will not impinge on gunner - behind him
  Toxic Gases - parts allowable to affect gunner
  Smoke - behind gunner
  Flash - short duration - behind gunner
  Weight transfer - perceived in $\leq$0.3 seconds.

The actual weapon firing conditions are probably less than firing an M-16 rifle. However, only through firing the actual weapon or a highly representative training aid will the gunner anxieties be reduced to produce a reliable performance from an individual in combat.

STINGER LAUNCH SIMULATOR

The firing of a Stinger weapon by every gunner is cost prohibitive. In addition to the cost of a weapon is the target, firing range and range control, safety and ordnance personnel. In order to effectively condition a gunner to firing conditions, a training simulator has been developed.

The first launch simulator was developed for the Redeye weapon system. Biomedical studies disclosed that firing the Redeye Eject Launch Simulator (RELS) induced the same gunner anxieties as firing the weapon. Also, that once a gunner had fired at least on RELS he was significantly more relaxed at the first time he fired an actual weapon. The results of biomedical tests and extensive interviews with gunners substantiated the need for a high fidelity launch simulator for the Stinger weapon system.

The Stinger Launch Simulator (STLS) has been designed to duplicate the Stinger weapon firing conditions. The exact duplication is essential particularly if a gunner does not have the opportunity of firing a weapon prior to a combat situation. The higher fidelity of the firing condition between the simulator and the weapon will result in a more confident, reliable and better trained gunner. To ensure the optimum cost-effective training aid, a training aid trade-off is shown in Table 1 relative to man/weapon performance requirements. This table takes the weapon operational characteristics and compares them to (1) Field Handling Training (FNT), (2) Tracking Head Trainer (THT), (3) Stinger Launch Simulator (STLS) and (4) other potential training aids.

Table 1. Training Aid Considerations

MAN/WEAPON PERFORMANCE	WEAPON	FHT	THT	STLS	OTHER
A. Handling					
Weapon weight <35 lbs	x	x	-		-
Shouldering weapon <4.0 sec	x	x	x	x	x
IFF connection <3.0 sec	x	x	x	x	x
Center of gravity					
Forward of shoulder ≤1.0 inch	x	x	-	x	-
Pursuit tracking					
Pointing error					
Low	x	x	x	x	x
Medium	x	x	x	x	
High	x	x	-	x	-
Portability					
5th percentile man	x	x	x	x	-
95th percentile man	x	x	x	x	x
Overall length	x	x	x	-	-
B. Engagement					
Activate to fire ≤10.0 sec	x	-	x	x	x
Target at launch	x	-	x	x	x
C. Environmental					
High temp (operating) 165°F	x	x	x	x	x
Low temp (operating) -25°F	x	x	-	-	-
D. Firing Conditions					
Noise <168 db	x	-	-	x	?
Recoil <0.8 lb/sec	x	-	-	x	x
Overpressure <3.0 lb per sq in	x	-	-	x	x
Backblast <150 meters	x	-	-	x	x
Toxcity <standards	x	-	-	x	x
Weight transfer ≤22.9 lbs	x	-	-	x	-
Flash min detect.	x	-	-	x	-

UNIVERSAL TRAINER

The STLS promises many product improvements in the future. The main thrust should be to provide a universal trainer, or one trainer that could be a Field Handling Trainer, Tracking Head Trainer, and Stinger Launch Simulator all in one. It could be easily modified to provide any of the following:

1. Field Handling Trainer (FHT) - Insertion of an inert missile to duplicate weight to provide FHT for weapons handling and reaction training (Figure 11).

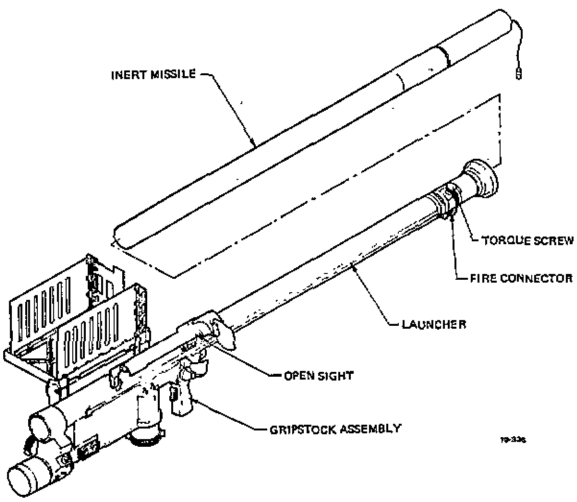


Figure 11. Field Handling Trainer

2. Tracking Head Trainer (THT) - Insertion of inert missile and multishop gas bottle or insertion of an 80 shot gas bottle in launch tube duplicating weight of missile would provide THT for use in MTS (Figures 12 and 13).

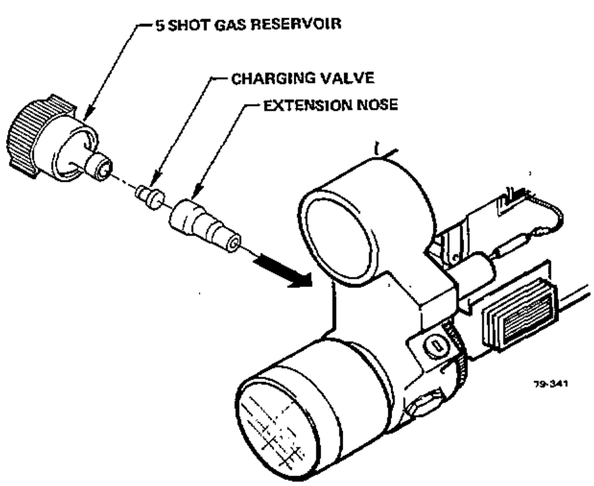


Figure 12. Multishop Gas Bottle

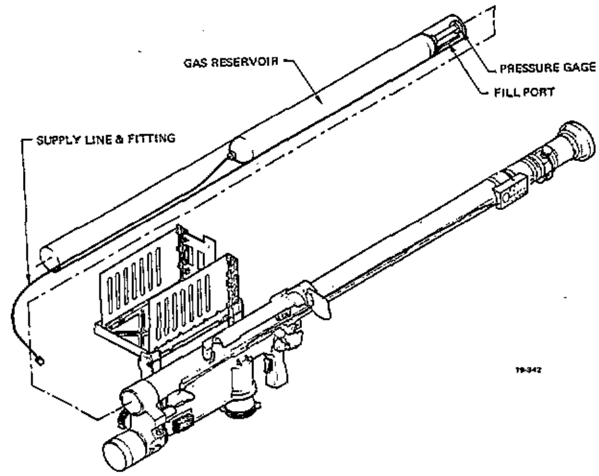


Figure 13. Tracking Head Trainer Multishot STLS Gas Reservoir

3. Performance Indicator - Addition to either STLS or STLS/THT to show gunner performance can be either mounted on launcher, or remote readout with transmitter mounted on launcher (Figure 14).

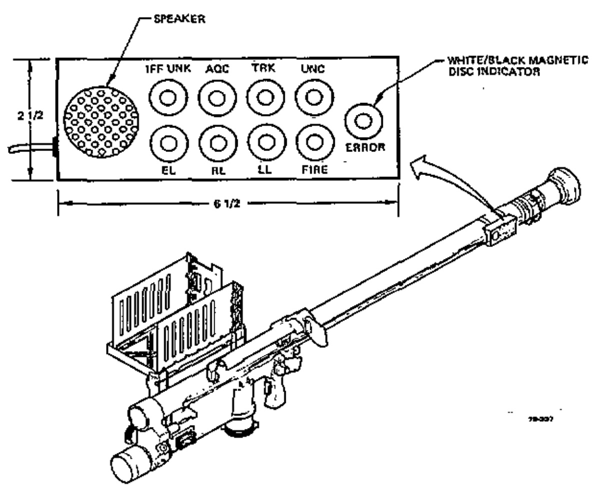


Figure 14. Performance Indicator

4. Optical Scoring Concept

a. 35 MM still camera with telephoto lens and automatic film advance.

b. Modified polaroid camera with special telephoto lens and automatic film eject.

c. Lightweight TV vidicon camera with telephoto lens and video recorder.

STLS is a truly versatile trainer and can provide total training simulation in one package (Figure 15).

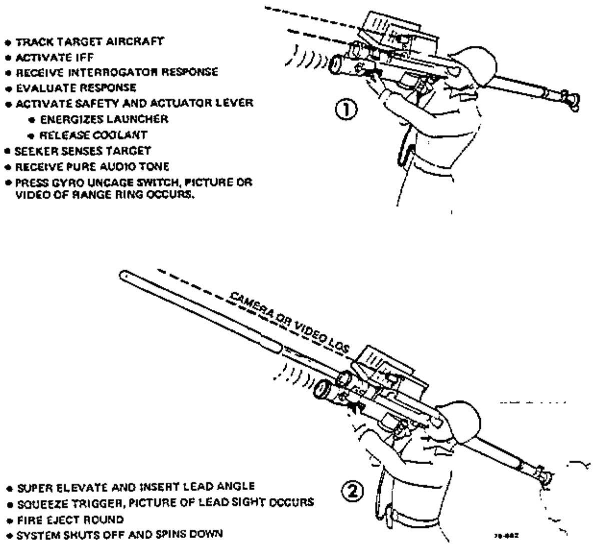


Figure 15. Video Scoring Sequence for STLS

CONCLUSION

A cost-effective training approach for weapon systems that have a high man-weapon interaction has been developed. This trainer, exemplified by STLS for Stinger, provides an added dimension of realism at a fraction of the weapon cost. The only alternative for Stinger is to do no hands on field firing. This does not seem reasonable in light of the requirement for the trainee gunner to kill a high-value jet aircraft on his first firing attempt.

Classroom training is important in Stinger as well as for other weapons. The exposure to the environment, noise of incoming aircraft, knowledge that you must perform in front of your peers and the apprehension associated with firing a live motor on the shoulder cannot be duplicated indoors.

The concept for STLS is simple and has potential for other weapon systems. The prefire sensor/tracking system and any other missile-mounted prefire devices can be integrated into the launch system. The next step is to simplify the missile by removing the guidance, warhead, sustainer motor, etc., so that a bare minimum system remains. Now a real threat can be safety engaged, tracked and fired upon with no danger. This could be a simple but effective training technique for many weapons, but at a minimum, it is key to weapons with high man-weapon interactions.

Consideration needs to be given to this type of trainer early in weapon development so appropriate development and hardware procurement can be accomplished in a timely manner. It can become part of the weapon GSE/logistics package and could be developed with the weapon at minimal cost.

Conclusions from TRASANA Technical Report No. 6-78[1], dated October 1978, concurs in the RELS and STLS concepts through the following statements:

> "Live firing exercises form the most important part of the gunners training, both in the unit and institution as is evidenced by the response to the RELS questionnaires. As one gunner commented, "Live firings puts it all together."

> "The RELS training package is an effective training aid to reduce fear and build gunner confidence."

REFERENCES

[1] Department of the Army, U.S. Army TRADOC Analysis Activity, White Sands Missile Range, TRASANA, Technical Report No. 6-78, dated October 1978, Redeye Weapons System, Volume 1 - Executive Summary.

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