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GUNNER AIMING PERFORMANCE AS A FUNCTION OF TARGET TANK SHAPE, S--ETC(U)
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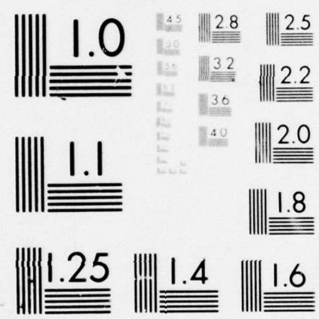


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Technical Note 8-77

# GUNNER AIMING PERFORMANCE AS A FUNCTION OF TARGET TANK SHAPE, SIZE AND SELECTION OF FIRING POSITIONS

Thomas A. Garry
Donald Campbell

July 1977
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Gunner aiming data are presented when engaging two kinds of main battle tank targets—the M60A1 and the Swedish Casemate which ostensibly present the engaging gunner with targets of significantly different shape and size. The data are analyzed in terms of target size and shape as a function of selection of (selected versus forced) firing positions.

Implications of the effects of tank design and presented target area on the performance of engaging enemy gunners are drawn.

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CONTENTS

# GUNNER AIMING PERFORMANCE AS A FUNCTION OF TARGET TANK SHAPE, SIZE AND SELECTION OF FIRING POSITIONS

## INTRODUCTION

The fact that target size affects the probability of achieving a hit on the target is very obvious. When firing under main front or range-type conditions, the relationship of size (or range) to hit probability is clear and unambiguous. Equally clear is the fact that regular, well-defined shapes—such as circles, squares, rectangles, ellipses, and rhomboids—present little in the way of challenge when a gunner must determine the geometric center of mass. Reference points are readily available and the human visual system is efficient at determining when these landmarks are equidistant and thereby define the center of the shape.

What is not obvious is that relationship of actual presented target size and shape when the target is intelligently interacting with the terrain but still constrained to achieve a particular mission. That mission is not merely to survive, but rather to deliver effective fires on an objective, and, concomittantly minimize its own vulnerability.

The Swedish Casemate tank and the M60A1, because of their dramatic differences in shape and size (Figures 1 and 2), provide a singular opportunity for examining these relationships with current hardware.

The data and discussion which follow represent the U. S. Army Human Engineering Laboratory's effort to establish a basic understanding of these phenomena and evaluate the issue as it might affect future tank design.

## APPROACH

A Swedish Casemate and an M60A1 were made available for the test.

An objective for the tanks was established at 1800 yards from the tank's line of departure.

Situated on that objective were two vertical markers painted in barber pole fashion for easy acquisition by both commander and gunner. These poles, 50 yards apart, defined the sector of responsibility for each attacking system. The advancing tanks had to be able to lay simulated fire from one pole to the other and along the entire length of the 50-yard sector.

Each tank was to assume four firing positions as it approached the objective. Only landfold was to be used for concealment because vegetative concealments would nullify the parameters of interest (size and shape of the tank).

Once a position had been selected, it was essential that both the tank commander and the gunner could see the objective and deliver simulated fires as described above.

Figure 1. M60A1 Tank.

Figure 2. STRV 103 (S-Tank).

The M60A1 positions were selected by a senior US Armor noncommissioned officer (NCO). The Swedish Casemate positions were selected by a lieutenant colonel (LTC) of the Swedish Armor Corps.

In this way, the positions selected were those suitable to and compatible with the design characteristics of the individual systems.

It would be improper to force both tank systems to use the same positions, thereby possibly biasing the situation in favor of one or the other.

In an attempt to gain some insight on how this bias might work, we subsequently had each tank system occupy the other's selected positions, thereby providing comparative data on forced positions versus selected positions.

## SUBJECTS

Six defender subjects were used to generate the data. Each held an 11E tanker's MOS and had successfully completed their Armor Advanced Individual training.

A briefing was prepared on the Swedish tank to instruct the subjects on where to deliver fire to achieve a K-kill.

A refresher briefing on the M60A1 was also provided.

## PROCEDURE

As each tank assumed its offensive position of maximum concealment by landfold (but able to simulate fire on the objective), each defender subject delivered simulated fire on the tank from each of three defensive positions located on the objective between the vertical markers. The attacking tanks were instructed to lay their guns first on the left vertical marker and then on the right marker as directed.

Each defender position was provided with a heavy duty friction head tripod upon which was mounted a pin registered 16mm gun camera and a collimated 8-power gun telescope with a reticle in the focal plane. This was used to aim at the tank. Aiming was to be accomplished quickly from a slight target offset. There was no detection requirement.

When satisfied with his aim point selection, the defender pressed a button which activated the camera and left a mark on the film indicating trigger pull.

The subject then proceeded in sequence to each of the other two defender positions and followed the same procedure. This provided 18 aim points (6 subjects x 3 defender positions = 18) on each tank. The tanks were next directed to lay their guns on the right vertical marker. The six defender subjects repeated the above procedure thereby producing 18 additional aim points for a total of 36 on each of the tanks.

When all the selected positions had been occupied and aim points selected, the entire procedure was repeated with the tanks occupying their forced positions.

## TEST CONDITIONS

| S-Tank | M60A1 |
|---|---|
| 4 Selected Positions | 4 Selected Positions |
| 2 Lay Points (L-R) | 2 Lay Points (L-R) |
| 3 Defender Positions | 3 Defender Positions |
| 6 Defender Subjects | 6 Defender Subjects |
| $\Sigma$ = 144 Aim Points | $\Sigma$ = 144 Aim Points |

| S-Tank | M60A1 |
|---|---|
| 3 Forced Positions | 3 Forced Positions |
| 2 Lay Points | 2 Lay Points |
| 3 Defender Positions | 3 Defender Positions |
| 6 Defender Subjects | 6 Defender Subjects |
| $\Sigma$ = 108 Aim Points | $\Sigma$ = 108 Aim Points |

## DATA AND RESULTS

We expected the test conditions to produce about 500 aim points.

Because of the nature of the terrain at the closest range, only one firing position could be found that was acceptable to both tanks. Therefore, there is no "forced" position for either tank at the 900-yard range.

The data consist of the following:

1. The variability of the aim points.

2. Target shape and the center of the aim points.

3. Target size:

   a. in selected positions.

   b. in forced positions.

4. The calculated hit probabilities for:

   a. M60A1

      (1) selected positions

      (2) forced positions

   b. Swedish Casemate

(1) selected positions

(2) forced positions

## Variability of Aimpoints

When the gun camera film was analyzed, we discovered that data recording malfunctions had eliminated many data points: about one-fifth of the film data lacked the essential trigger pull marks. The remaining or good data fortunately are distributed about equally across all defenders and conditions. This results in approximately 30 data points per target and only these are used in the analysis.

Each presented target had a 4-foot-square black and white reference marker nearby and in the camera's field of view. Because of its superior definition, we used it to measure subject to subject changes in aim point through the simple change in location of the marker.

Table 1 presents these data as a standard deviation in feet and mils. The variability is of the order of .2 mils. Targets were presented starkly without garnish or camouflage of any kind.

## Target Shape and the Center of the Aim Points

As the film was read, it was apparent that the defenders were selecting aim points generally in the region of the presented target's geometric center. Because the film was poorly exposed, the *precise center of the aim points could not be determined in many* cases, but, nevertheless, a visual estimate could be made and is presented in Figures 3 through 6.

The estimate was achieved by dividing the aim points so that one-half were above the dividing line and the other half below. In similar fashion, the aim points were divided left and right. The shape of these tanks did not prevent the gunner from laying accurately on the target.

## Target Size - Selected Versus Forced Positions

The data in Table 2 express the relationship of presented target size of the two tanks between "selected" firing positions and those that they were "forced" to assume.

Overall, the S-tank showed some advantage in the selected positions. Not so much so in the horizontal dimension, but substantially so in the height dimension; 2.4 feet for the S-tank versus 4.0 feet for the M60 on the average.

But, in the "forced" positions, the M60 does as well as the S-tank in both dimensions.

In fact, Table 2 (target size in feet) shows that in the forced positions the M60 often does better than the S-tank in the critical elevation dimension.

It seems clear, then, that the S-tank's size alone is not the determining factor in presented target area. It must be able to find and take advantage of terrain if its design characteristics are to be meaningfully employed. Thus, it is simplistic to talk only of the size of the S-tank without regard for the interaction of terrain.

TABLE 1

Standard Deviation of Aiming Performance Against the M60A1 and the S-Tank Expressed in Feet and Mils

| | | Standard Deviation | | | |
|---|---|---|---|---|---|
| | | Feet | | Mils | |
| Position | Range | AZ | EL | AZ | EL |
| **SELECTED** | | | | | |
| S-Tank | | | | | |
| 4 | 1770 | .8 | 1.0 | .2 | .2 |
| 6 | 1590 | .6 | .7 | .1 | .1 |
| 8 | 1200 | .7 | .6 | .2 | .2 |
| 2 | 900 | .8 | .3 | .3 | .1 |
| M60 | | | | | |
| 1 | 1770 | .7 | .6 | .1 | .1 |
| 3 | 1680 | .8 | .6 | .2 | .1 |
| 5 | 1230 | .4 | .7 | .1 | .2 |
| 2 | 900 | .6 | .6 | .2 | .2 |
| **FORCED** | | | | | |
| S-Tank | | | | | |
| 1 | 1770 | .7 | .9 | .1 | .2 |
| 3 | 1680 | .9 | 1.0 | .2 | .2 |
| 5 | 1230 | .5 | .6 | .1 | .2 |
| 2[a] | | | | | |
| M60 | | | | | |
| 4 | 1770 | .9 | .6 | .2 | .1 |
| 6 | 1590 | 1.0 | .8 | .2 | .2 |
| 8 | 1200 | .5 | .6 | .2 | .2 |
| 2[a] | | | | | |

[a]No "forced" position was available at the 900-yard range.

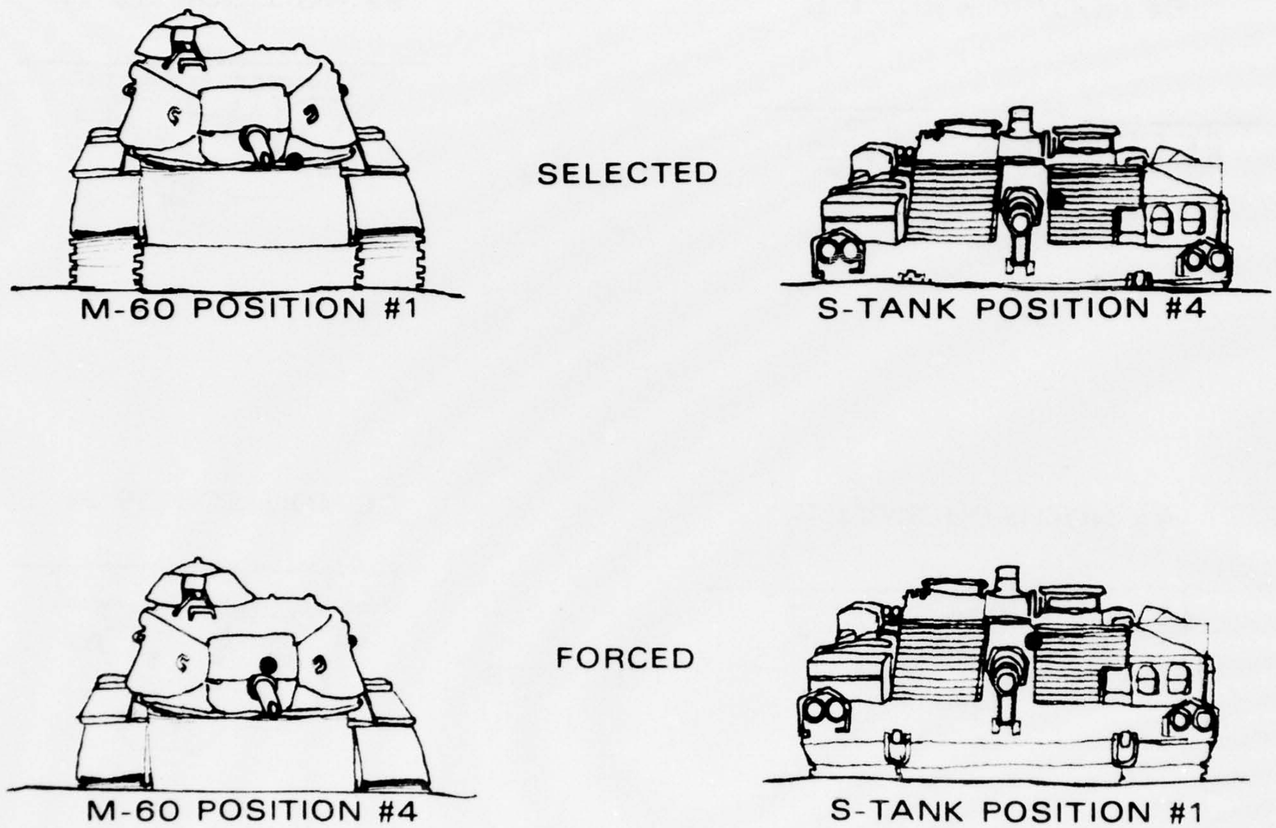


Figure 3. The gunners' approximate aim points against attacking tanks in Positions 1 and 4.

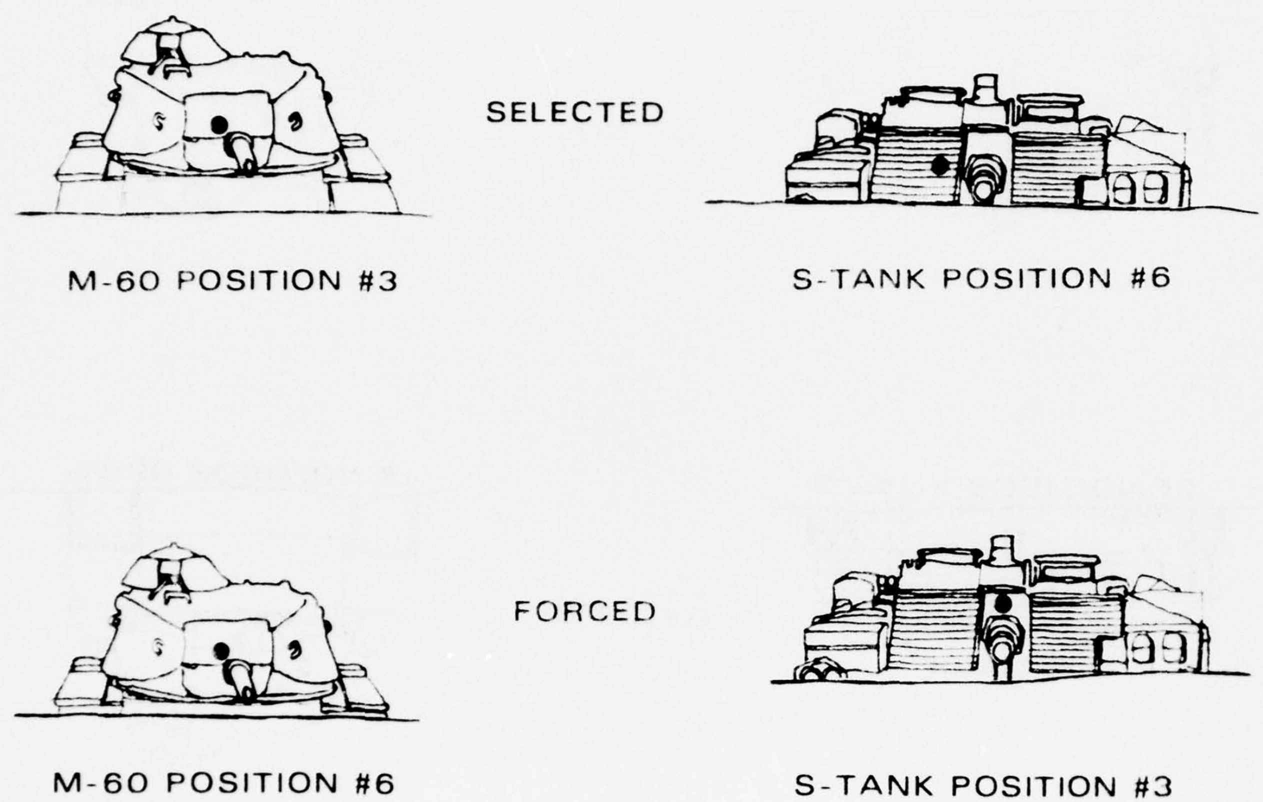


Figure 4. The gunners' approximate aim points against attacking tanks in Positions 3 and 6.

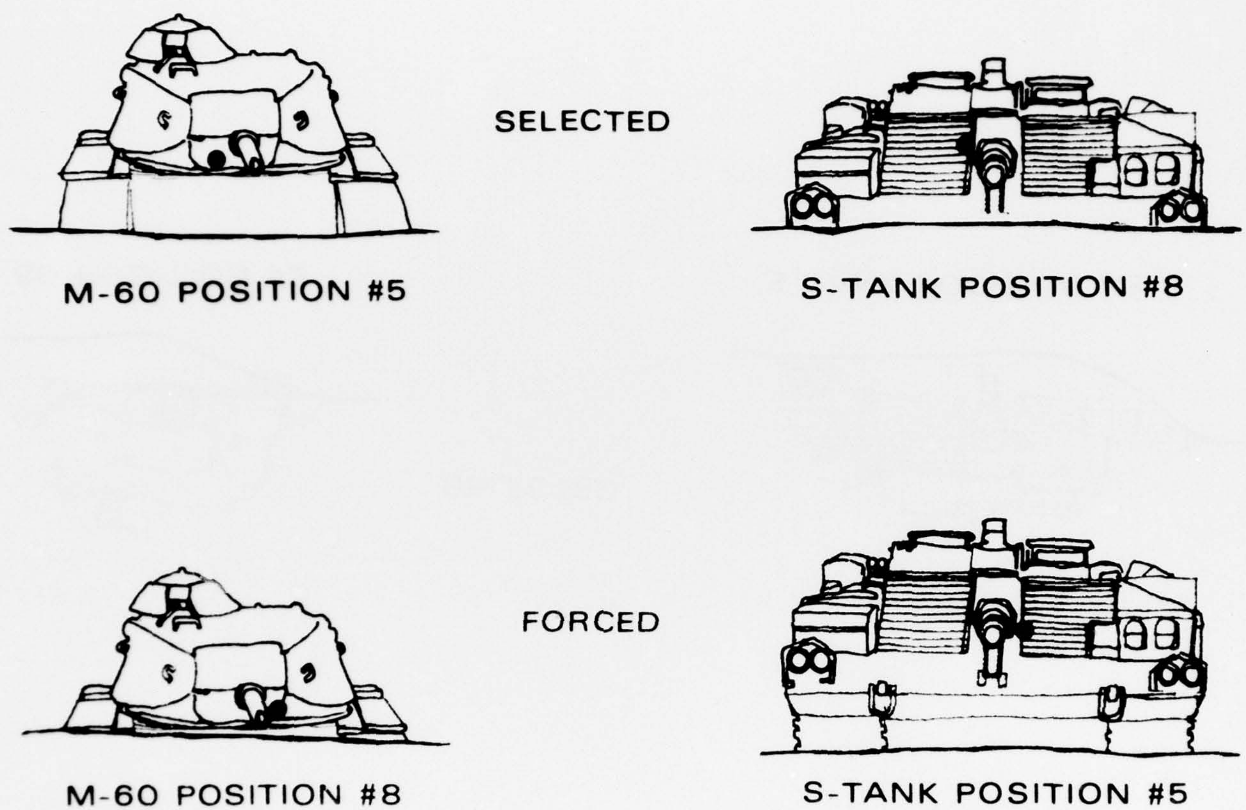


Figure 5. The gunners' approximate aim points against attacking tanks in Positions 5 and 8.


Figure 6. The gunners' approximate aim points against attacking tanks in Position 2.

## TABLE 2

Presented Target Size in Mils and Feet As a Function of Two Sets of Firing Positions, Selected and Forced

| Position | Range | Target Size: Mils AZ | Mils EL | Feet AZ | Feet EL |
|---|---|---|---|---|---|
| **SELECTED** | | | | | |
| S-Tank | | | | | |
| 4 | 1770 | 1.8 | .6 | 9.7 | 3.1 |
| 6 | 1590 | 1.9 | .4 | 8.9 | 1.8 |
| 8 | 1200 | 2.6 | .5 | 9.4 | 1.9 |
| 2 | 900 | 3.4 | 1.1 | 9.1 | 3.1 |
| M60 | | | | | |
| 1 | 1770 | 1.9 | 1.1 | 9.8 | 5.8 |
| 3 | 1680 | 1.9 | .7 | 9.7 | 3.5 |
| 5 | 1230 | 2.7 | 1.1 | 10.0 | 4.0 |
| 2 | 900 | 2.5 | 1.0 | 6.9 | 2.8 |
| **FORCED** | | | | | |
| S-Tank | | | | | |
| 1 | 1770 | 1.6 | .9 | 8.5 | 4.6 |
| 3 | 1680 | 1.6 | .4 | 7.8 | 1.8 |
| 5 | 1230 | 2.5 | 1.1 | 9.2 | 4.0 |
| M60 | | | | | |
| 4 | 1770 | 1.7 | .8 | 9.1 | 4.3 |
| 6 | 1590 | 1.4 | .5 | 6.5 | 2.3 |
| 8 | 1200 | 2.0 | .9 | 7.1 | 3.1 |

## Hit Probabilities on S-tank Versus M60A1 Targets

Target area alone is insufficient to describe the probability of obtaining a hit. Errors in the vertical plane for fall of shot are always greater than those in azimuth.

Obviously, two targets of equal area could present entirely different challenges to the engaging gunner from a ballistic standpoint.

The hit probabilities are presented for both dimensions of the target, horizontal and vertical, in Table 3 and are derived from Figure 7.

It should be noted that the curves of Figure 7 are for a 7.5-foot by infinity target. Consequently, an adjustment for actual target size was necessary before employing these curves. The appropriate standard deviations for these curves were obtained by multiplying the computed standard deviations by the quotient of 7.5 divided by the actual target dimension.

Because of ballistic characteristics of tank ammunition, an engaging gunner gains an advantage as the target gets larger in the vertical plane.

Therefore, an M60A1 turret, while higher (taller) or more exposed than the S-tank in the vertical plane, could still have a smaller exposed area than the wide and low S-tank striving to look over a small berm and deliver fire.

But, the vertical plane is where the gunner needs the assistance in hitting the target. Therefore, a vertical exposure of lower total area is a more vulnerable exposure than a larger but closer to the ground exposure.

The data in Table 3 for "selected" positions certainly suggest an advantage for the S-tank survivability in most cases. The probability of a hit in the vertical plane on the average is .87 as opposed to 1.00 for the M60. This difference of .13 is nevertheless considerably short of estimates based on height alone without regard for terrain interaction.

In the "forced positions," ones they might have to accept if hasty emplacement is called for or previous reconnoiter is denied them, the two systems begin to look very similar, $Ph_E$ of .95 for the M60 and $Ph_E$ of .88 for the S-tank, a difference of only .07.

The calculation of hit probabilities requires, in addition to the standard deviation of the aiming error, a measure of the bias or mean of the distribution. This derives from the standard procedure of firing at a well-defined aim point. However, in this case there was no well-defined aim point such as a cross or sphere. Consequently, we have taken the bias of the distribution to be zero. Because this may be somewhat unreal, we recalculated our hit probabilities employing a bias of 1 foot. However, this resulted in no practical change in Ph in either dimension.

Since it is conceivable that the bias might become large through camouflage painting (making center of mass more difficult to judge) or the addition of garnish, additional hit probabilities are presented in Table 4 for two larger values of bias. These hit probabilities suggest the importance of inducing large biases in the gunners' aiming behavior. However, it may be more important, all other things being equal, to place emphasis on deceiving (through use of terrain, foliage, camouflage, etc.) the visual system of the enemy gunner than to emphasize target height reduction for its own sake.

TABLE 3

Probability of Obtaining a Hit On the S-Tank and M60A1 for Two Sets of Firing Positions, Selected and Forced

| Position | Range | $Ph_A$ | $Ph_E$ |
|---|---|---|---|
| **SELECTED** | | | |
| S-Tank | | | |
| 4 | 1770 | 1.00 | .85 |
| 6 | 1590 | 1.00 | .81 |
| 8 | 1200 | 1.00 | .80 |
| 2 | 900 | 1.00 | 1.00 |
| M60 | | | |
| 1 | 1770 | 1.00 | 1.00 |
| 3 | 1680 | 1.00 | 1.00 |
| 5 | 1230 | 1.00 | 1.00 |
| 2 | 900 | 1.00 | .99 |
| **FORCED** | | | |
| S-Tank | | | |
| 1 | 1770 | 1.00 | .96 |
| 3 | 1680 | 1.00 | .69 |
| 5 | 1230 | 1.00 | 1.00 |
| M60 | | | |
| 4 | 1770 | 1.00 | 1.00 |
| 6 | 1590 | 1.00 | .87 |
| 8 | 1200 | 1.00 | .98 |

Hit probabilities were calculated from the three values of target size, the mean of the distribution of aim points and their standard deviation. A Nomograph describing these relationships was obtained from the U.S. Army Ballistic Research Laboratories to compute the values of Ph presented in this report.

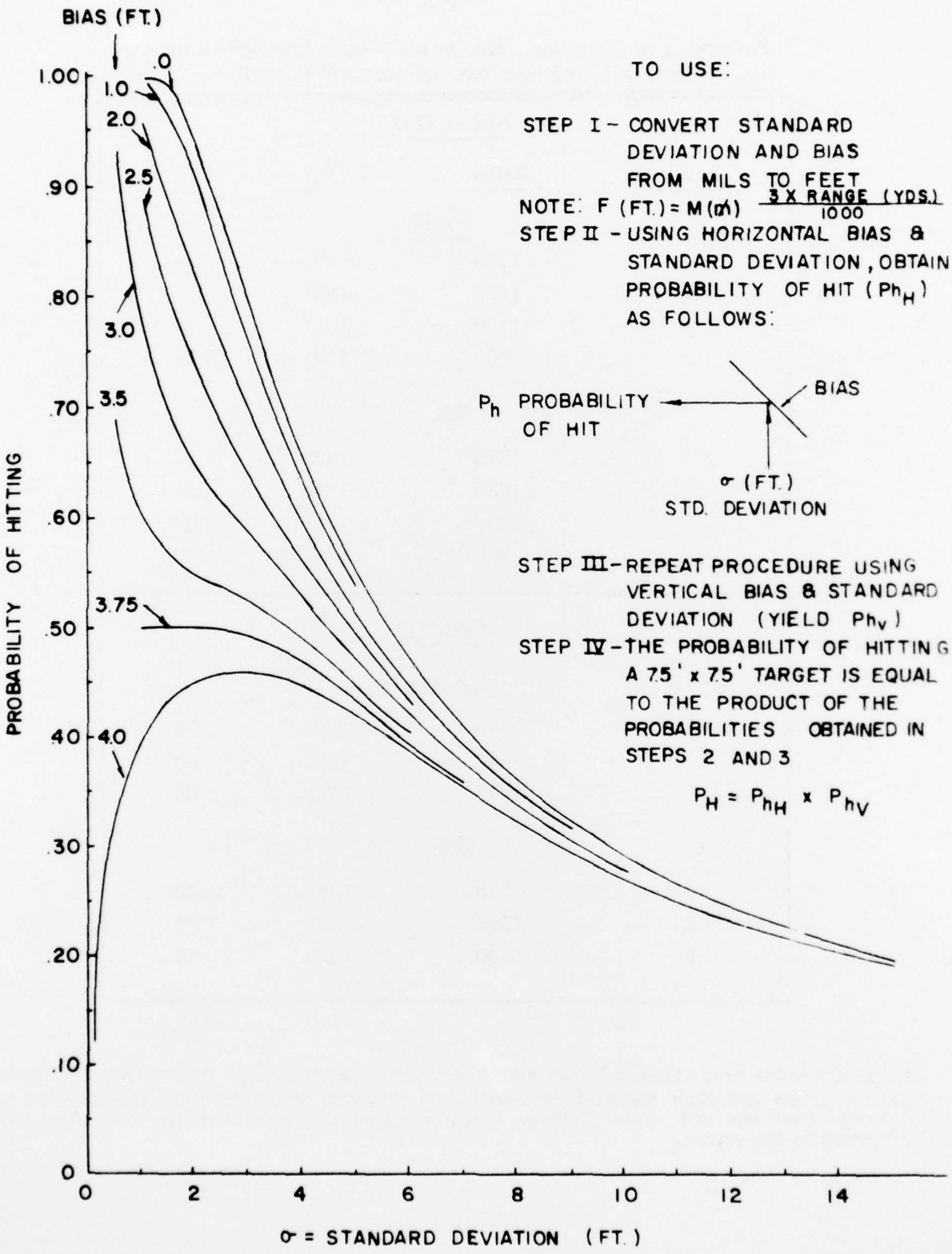


Figure 7. Probability of hitting a 7.5-foot by infinity target.

TABLE 4

Hit Probabilities for Two Values of Bias on the M60A1 and the S-Tank in Selected Versus Forced Positions

| | | Bias - 2 Feet | | | Bias - 3 Feet | | |
|---|---|---|---|---|---|---|---|
| Position | Range | $Ph_A$ | $Ph_E$ | Ph | $Ph_A$ | $Ph_E$ | Ph |
| **SELECTED** | | | | | | | |
| S-Tank | | | | | | | |
| 4 | 1770 | .97 | .72 | .70 | .90 | .61 | .55 |
| 6 | 1590 | 1.00 | .71 | .71 | .95 | .59 | .56 |
| 8 | 1200 | 1.00 | .70 | .70 | .89 | .60 | .53 |
| 2 | 900 | 1.00 | .99 | .99 | .89 | .81 | .72 |
| M60 | | | | | | | |
| 1 | 1770 | 1.00 | 1.00 | 1.00 | .95 | .85 | .81 |
| 3 | 1680 | .99 | .95 | .94 | .90 | .76 | .68 |
| 5 | 1230 | 1.00 | .91 | .91 | .82 | .71 | .58 |
| 2 | 900 | 1.00 | .90 | .90 | .89 | .70 | .62 |
| **FORCED** | | | | | | | |
| S-Tank | | | | | | | |
| 1 | 1700 | 1.00 | .88 | .88 | .93 | .66 | .61 |
| 3 | 1680 | .97 | .58 | .56 | .80 | .55 | .44 |
| 5 | 1230 | 1.00 | .95 | .86 | .96 | .75 | .72 |
| M60 | | | | | | | |
| 4 | 1770 | .97 | .97 | .94 | .80 | .80 | .64 |
| 6 | 1590 | .96 | .74 | .71 | .77 | .62 | .48 |
| 8 | 1200 | 1.00 | .87 | .87 | .91 | .68 | .62 |

## DISCUSSION

The data presented above represent only one military advisor for emplacing each tank and a single terrain site at Fort Knox.

Some might argue that these results, therefore, merely reflect differences between the advisors skill in emplacing their tanks or that a different terrain site would produce entirely different results. These sources of variation could probably be dealt with only by having several advisors and several terrain samples. This was not possible.

Whatever restrictions may apply to these data because of limited conditions, we believe that this test nevertheless provides insight regarding design characteristics and terrain interactions. Our perceptions of those relationships are provided in some detail below.

Reduced height alone will not guarantee improved battlefield survivability for a tank.

While size obviously counts for something, it is a collectable dividend only when synergistically released by the intelligent use of terrain. And most assuredly, there will be times when ideal terrain is available. It would be unwise, however, to develop designs and tactics predicted solely on this premise.

Consequently, tank size should not be pursued merely for presenting a smaller target, but rather it should be developed via a cogent philosophy and be an integrated outcome of mobility and agility, weight, armor protection, cost, fire power, and especially tactics and use of terrain, to cite most of the more salient characteristics.

Of course one can rationally argue that in the "open," a larger tank is hit more readily, other things being equal, than a smaller one.

However, this smallness may not be a desirable outcome of a design should it sacrifice the commander's vision of the terrain ahead or if internal crowding produces a decrease in vehicle fightability.

Indeed, conceivably it might make greater sense to enlarge the tank's silhouette with an external lightweight armor applique, thereby accepting a higher probability of hit in exchange for a diminished kill probability.

In the final analysis, armor is the combat arm of decision—not the combat arm of survival. And in the final assault, any tank becomes a large and a hitable target. So there are good reasons for building a tank without emphasizing target size and related Hp as the limiting design characteristic.

As one analyst[1] has pointed out, turret size and therefore the weight of our tanks could be significantly reduced by simple design changes (in our breech rings). The addition of weight to the breech ring would allow the trunnions to be moved back along with a reduction in the length of recoil. The space used by the gun would be reduced and allow for a reduction in the size of the turret.

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[1]Zaroody, S. The heavy breech principle for tank guns. BRL Memorandum Report No. 2242, U.S. Army Ballistic Research Laboratories, Aberdeen Proving Ground, Md, November 1972.

The Russians have achieved a smaller turret design, improved safety and survivability and a significant weight reduction by simply removing the ammunition from the turret and retaining a heavy breech ring.

In neither of these cases is size pursued for its own sake. Size is the by-product of the logical consideration of design options related to mission achievement and the perceived threat.

In the matter of tank shape, it too will emerge as a logical consequence of the design options.

It is inconceivable that tank shape would develop as some sort of novelty independent of technological advances in armor and slope design and the evolution of new ammunitions.

The assertion that the S-tank enjoys a significantly lower probability of hit merely by virtue of its size cannot be supported by this field comparison.

When constrained to lay fire on the objective, it was necessary to hydropneumatically elevate the tank (Figure 5), thereby restoring it almost to its maximum height.

The turreted M60 on the other hand, when it achieved hull defilade, presented a small target in elevation and azimuth. Only the turret's width established the horizontal dimension. To deliver fire, it merely elevated its gun or slewed the turret. There is no requirement to move from hull defilade.

An examination of the M60A1 in comparison with the S-tank reveals that the S-tank has *only 10 inches of space* above the gun mounting. The M60A1, however, has a full 30 inches above the trunnion. That means that regardless of the terrain advantages which may be seized, the M60A1 is forced to expose this minimum in order to fire.

Paradoxically, the M60A1 could be even taller than it is and present a smaller target when defiladed, provided only that the trunnions were put higher in the vehicle. (Optics also would have to move up in real life.)

Now, this theoretically very tall vehicle could poke its muzzle over the berm with nothing in the tank higher than it. The chances of hitting such a presented target would be minuscule. Yet, measured in the motor pool with a standard M60A1, our high trunnioned theoretical tank would appear to be considerably more vulnerable based on height alone without considering how it would use terrain to present essentially only the gun barrel as a target.

It is not seriously suggested that high trunnion positioning be pursued in and of itself. But rather, it is to say that in tank design, space above the trunnions should be at the barest minimum.

## CONCLUSIONS AND IMPLICATIONS

The principal conclusion to be drawn from this field test is that neither size nor shape can be treated as independent design features. Both are and will continue to be inextricably bound up with fundamental design philosophy of which they will be only an ancillary outcome.

Comparative testing of tank systems should always take into account the unique design characteristics of each system when measuring performance in a tactical setting. Terrain selected for firing positions by an S-tank commander is likely to prove wholly unacceptable to the commander of an M60. When this principal is overlooked, the emergent data are likely to be biased.

The S-tank's size alone is not the determining factor in presented target area.

When denied the use of selected or favorable terrain, the S-tank often presented a larger vertical target than the M60A1.

Overall, the S-tank enjoyed some advantage in the preferred positions.

To fully exploit its unique size advantage, the S-tank must be able to find and take advantage of favorable terrain.

Advances in camouflage painting and the addition of garnish and other eye deceiving techniques may have greater influence on hit probability than size alone.

The configuration of a tank with respect to its trunnions and the space provided above them is of greater importance for survivability than height as measured in the motor pool.