UNITED STATES
MILITARY ACADEMY
WEST POINT, NEW YORK

SENIOR CONFERENCE
XX

THE
"MILITARY REFORM"
DEBATE:
Directions for the Defense Establishment for the
Remainder of the Century

3-5 June 1982

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THE CASE FOR MORE EFFECTIVE, LESS EXPENSIVE WEAPON SYSTEMS: WHAT "QUALITY VERSUS QUANTITY" ISSUE?

Pierre M. Sprey
THE CASE FOR MORE EFFECTIVE, LESS EXPENSIVE WEAPON SYSTEMS: WHAT "QUALITY VERSUS QUANTITY" ISSUE?

Introduction

Unfortunately, much of the defense debate revolves around buzzwords. "Second echelon," "power projection," "smart weapons" come to mind as a few particularly imprecise and misleading examples. One of the most fashionable of last year's crop of buzzwords is "quality versus quantity." This slogan is intended to characterize the fundamental weapons procurement dilemma as a choice between a few superb but unfortunately expensive weapons or large numbers of cheap but ineffective weapons. The issues underlying this rather shallow characterization reach down to the roots of our deteriorating combat capabilities; it is these underlying issues that are worth pursuing.

The Scope of the Problem

Let us start by examining how much of a "quantity" problem we have. Figure 1 traces the annual production rates since 1950 of three of our most important weapons: tanks, fighters and surface warships. In 1952, we produced over 6,500 tanks; today we are producing 600 to 700 per year. In 1951, we procured over 6,000 fighters; today, we are buying less than 300. Warship deliveries peaked in 1963 at 15 per year; this year we are down to 8 and by 1986 we'll be down to 6 per year. This amounts to a staggering decrease in "quantity" over the last 20 to 30 years.

To understand the causes of this decrease it is necessary to look at spending, then and now for the tanks, fighters and ships produced.

The tanks we produced in 1952 cost us about $2 billion in FY 83 constant dollars. We are spending the same amount today to buy 1/10th as many tanks.
DO WE HAVE A PROBLEM?

**TANKS PER YEAR**

**FIGHTERS PER YEAR**

**WARSHIPS**

*Figure 1*

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The 6,000+ fighters we budgeted in 1951 cost about $7 billion (FY 83$). In the FY 83 budget we are buying 1/20th as many fighters for over $11 billion. Ships present a similar picture.

One thing is clear: decreasing real expenditures are not the cause of the "quantity" problem.

The Argument for "Quality"

In this discussion, we shall follow the steps of the typical argument for "quality" weapons and, wherever possible, test each step against the evidence. These are three steps to the typical argument:

Step 1: We have always bought the best for our boys, and the best costs money. This is easily tested by looking at a sample of weapons that worked notably well in past wars and seeing whether they typically cost more than the ones that did poorly.

Step 2: In any case, the real world alternatives we face today are between expensive but very effective systems and cheaper, much less effective ones. This proposition can be tested by looking at a sample of today's expensive systems and their cheap alternatives, across a spectrum of missions.

We will then compare in some detail the effectiveness of the expensive system versus the cheap alternative in two of these missions, armor and air-to-air combat. We shall use explicit effectiveness criteria based on combat experience.

Step 3: In any case, much as we would like to choose the simple, cheap alternative, the rapid increase in Soviet "quality" forces us to select the option of fewer, more complex, more costly weapons. The validity of this final step can be directly
tested by evaluating the latest Soviet "quality" tank and "quality" fighter against exactly the same set of effectiveness criteria we used in Step 2 to compare the simple versus the complex U.S. weapons.

The evidence assembled in testing these three propositions should lead us to some useful overall insights on the connection, or lack thereof, between complexity and effectiveness.

**History: Were the Best Weapons the Most Expensive?**

Table I represents a sample of weapons that were notably successful in WWII and Vietnam combat, together with their unsuccessful alternatives or opponents.

It is appropriate to start with the most basic -- and, in some ways -- the most important weapon of war, the rifle. In the first infantry actions of the Vietnam war, Free World troops were usually equipped with the M-14, the heavy, handsomely-fabricated 7.62 mm weapon strongly preferred by the Army hierarchy over the light and much cheaper 5.56 mm AR-15. In these first rifle firefights against Viet Cong bands using the fully automatic AK-47, the slow-firing M-14 came off second-best; the Viet Cong usually established fire superiority and M-14 riflemen suffered unfavorable casualty exchange ratios. But during the same period, U.S. Special Forces units and some South Vietnamese infantry were using the AR-15 and achieving very favorable results in firefights against the AK-47. The $75 AR-15 proved to be more accurate, more reliable, and remarkably more lethal than the $295 M-14; equally important, it permitted the rifleman to carry three times as many rounds in his fighting load. The disparity in combat results between
<table>
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<tr>
<td>AR-15</td>
<td>M-14</td>
<td>AR-15: TRIPLE THE ROUNDS; MORE LETHAL, ACCURATE AND RELIABLE IN SVN.</td>
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<tr>
<td>$75</td>
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<tr>
<td>T-34</td>
<td>PANZER IV</td>
<td>T-34: CRUDE AND RELIABLE; HIGHER V0; LOWER; WIDER TRACKS.</td>
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<td>TOWED 105 MM</td>
<td>175 MM SP</td>
<td>175MM: CONSTANT BREAKDOWNS AND TUBE REPLACEMENTS IN VN.</td>
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<tr>
<td>$170K</td>
<td>$560K</td>
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</tr>
<tr>
<td>JAP DESTROYER</td>
<td>U.S. CRUISER</td>
<td>DESTROYER: HAD HIGHLY RELIABLE, LETHAL, LARGE TORPEDO; CRUISER DIDN'T.</td>
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<tr>
<td>AIM-9D WINDER</td>
<td>AIM 7-D/E SPARROW</td>
<td>AIM 7D/E: HAD P*K = .08, 1/3 THAT OF AIM 9-D.</td>
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<tr>
<td>$14K</td>
<td>$44K</td>
<td></td>
</tr>
<tr>
<td>P-51</td>
<td>P-38</td>
<td>P-38: BIG/VISIBLE, SLUGISH TRANSIENTS, TWIN ENGINE VULNERABILITY. WITHDRAWN FROM EUROPE.</td>
</tr>
<tr>
<td>$51K</td>
<td>$125K</td>
<td></td>
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</tbody>
</table>
the two rifles was so marked that General Westmoreland, reluctantly and
against the bitter opposition of the Army Staff, demanded that the AR-15 be
issued to all U.S. troops in Vietnam. 3

Moving back in time to WWII and the Eastern Front, scene of the largest
tank battles in history, the two principal tanks facing each other were the
primitive, crudely fabricated Soviet T-34 and the beautifully
engineered and machined German Panzerkampfwagen IV. The skilled and
experienced German tankers were shocked by the superiority of the Russian
tank. Crude and simple it was. But its wider tracks allowed it to move when
German tanks were bogged down in the deep Russian mud; when the finely-crafted
running gear of the Panzers was frozen stuck, the sloppy tolerances of the
T-34s kept them rolling. The T-34's low sloping armor and its less flammable
diesel fuel made the Panzer IV's short cannon seem puny and inadequate; in
contrast, the high velocity, long-barrelled 76.2 mm and later 85 mm of the
T-34 could penetrate and destroy the Panzer IV from any direction. Tank for
tank, the cheaper T-34 was more effective than the more expensive Panzer IV.
Even worse for the Germans, the Russians were able to produce more than three
for every one the Germans produced, in part due to the relative simplicity
of the T-34. The superior effectiveness and much greater numbers of the T-34
were a crucial factor in winning the war for the Russians.

Though all the examples in Table I are worth discussing, one final
example is selected here: the P-51 versus the P-38 in WWII European air-to-
air combat. The Army Air Force's "school solution" fighters for defeating
Messerschmitt 109s and Focke-Wolf 190s were the large and expensive P-38 and
P-47, respectively $125,000 and $90,000. The P-51 was a much lower priority
project that had to be ordered by the RAF as a close support aircraft in order
to survive at all. High losses in actual combat against German fighters showed that the complex, expensive P-38 was an unsatisfactory solution and it was ordered removed from Europe by the AAF theater command during the spring of 1944. Why? Because, although the P-38 was fast, it was too large and too visible, too sluggish in transient maneuvering and it suffered from twin engine vulnerability -- that is, if either engine was hit, the aircraft was likely to burn or explode.

By the time the P-38 was forced to withdraw from Europe, the P-51 was establishing itself as one of the finest major fighters of the war, arguably the finest in the eyes of many air historians. And, perhaps less widely known, the P-51 with its superior effectiveness characteristics was also one of the least expensive fighters of the war at $51,000 apiece.  

**Today's Choices: Are the Expensive Ones More Effective?**

Table II shows a sample of missions or functions and, for each, the expensive weapon that we have elected to buy. For each expensive choice, a much cheaper alternate is shown. Cost differences range from 2 to 1 to 75 to 1, so clearly the cheaper choices permit building much larger forces. Can we be sure the differences in effectiveness go the other way?

Effectiveness comparisons in two of the mission areas, armor and air-to-air, will be examined in subsequent sections. Only brief comments can be offered here on some of the other choices.

In air defense, there is good reason to believe that DIVAD, like all previous radar-directed guns, will do poorly against maneuvering attack fighters. On the other hand, old optically-aimed guns (with much poorer ballistics than the Oerlikon 20 mm) with well-trained or experienced gunners
<table>
<thead>
<tr>
<th>MISSION</th>
<th>CHEAP</th>
<th>EXPENSIVE</th>
<th>COST RATIO</th>
<th>FY 82 $</th>
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<tr>
<td>ARMOR</td>
<td>M-60A1</td>
<td>M-1</td>
<td>3:1</td>
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<td>AIR DEFENSE</td>
<td>OERLIKON 35MM</td>
<td>DIVAD</td>
<td>30:1</td>
<td>.35M/10M</td>
</tr>
<tr>
<td>ANTITANK</td>
<td>106 RR</td>
<td>TOW</td>
<td>30:1</td>
<td>.25K/7.5K</td>
</tr>
<tr>
<td>ASW ESCORT</td>
<td>KORTENAER</td>
<td>SPRUANCE</td>
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<tr>
<td>SUBMARINE</td>
<td>210 (DIESEL)</td>
<td>SSN-688</td>
<td>8:1</td>
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<td>AIR-TO-AIR</td>
<td>F-16A</td>
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<td>TANK HUNTING</td>
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<td>CLOSE SUPPORT</td>
<td>A-4M</td>
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<td>INTERDICTION</td>
<td>A-7</td>
<td>F-18</td>
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<td>ANTITANK AMMO</td>
<td>30MM</td>
<td>I²R MAVERICK</td>
<td>75:1</td>
<td>1K/75K</td>
</tr>
</tbody>
</table>

ARE ANY OF THE EXPENSIVE CHOICES CLEARLY MORE EFFECTIVE?
have done devastatingly well against Free World fighters in Korea, Vietnam and Israel, as evidenced by the 4,000 or more jets they shot down -- almost all of them during a maneuvering attack pass.

In heavy antitank weapons, there are reasons to believe that the TOW may do nearly as poorly as the .013 probability of kill scored by the Soviet Sagger antitank missile in the Yom Kippur War. Although the TOW probably has somewhat more accurate guidance than the Sagger, it suffers from similar deficiencies in excessive exposure of the gunner during missile guidance and an unacceptably low rate of fire (.7 to 1.0 rounds/minute). The 106 mm recoilless, though old and far from the best in today's recoilless technology, can get 8 rounds per minute and hit well out to 800 m, which covers at least 75% of the firing opportunities in actual tank combat. It also costs 1/30th as much per round as the TOW, ammunition being the dominant cost for both systems. It is unlikely that a war reserve stockpile of 1/30th fewer TOW rounds than 106 mm rounds will defend us better against a sustained attack by 20,000 or more tanks.

In submarine warfare, the USN has long since abandoned the diesel-electric attack submarine in favor of the faster and longer range nuclear submarine. But modern diesel-electric submarines on batteries are much quieter than nuclear submarines, need to snorkel only 5% of the time and can go 12,000 km or more. We could have eight 1,200 ton diesel-electric submarines for every SSN-688 for good. Given that diesel-electrics rarely fail to sink high value surface warships in NATO exercises and do very well in sub-to-sub exercises, is the diesel-electric the less effective choice for all submarine missions? The Soviet, French, and British Navies clearly think otherwise.
When effectiveness is examined, not on the basis of hypothetical models of combat or of technological promises, but by understanding actual combat and exercise evidence, then similar doubts can be raised about each of the remaining expensive choices in Table II. Not a single one of the 10 expensive choices is clearly more effective; in at least 7 cases, the available combat and test or exercise data strongly supports an opposite conclusion.

Air-to-Air Effectiveness:
F-15 versus F-16

The first of the two sample areas in which we shall compare, in somewhat more detail, the effectiveness of an expensive alternative with a cheaper one is the air-to-air mission. We shall compare the $30 million F-15 and the $15 million F-16 in terms of the four principal effectiveness characteristics that contribute to victory in air-to-air combat: achieving surprise bounces and avoiding being surprised; outnumbering the enemy in the air; out-maneuvering the enemy to reach firing position (when surprise fails); and achieving reliable kills within the brief firing opportunities presented by combat. Table III summarizes the comparison results. Surprise is first because, in every air war since WWI, somewhere between 65% and 85% of all fighters shot down were unaware of their attacker. The F-16 is superior in achieving surprise because it is about half the size of the large and highly visible F-15; even more important to visual detection, the F-16 smokes half as much as the F-15. In the electromagnetic spectrum, both fighters need to turn off their radars to assure surprise against an enemy equipped with a competent radar warning receiver.

In outnumbering the enemy in the air, the F-16 has a sizable advantage. We can buy and operate two F-16s for the same cost as one F-15. In addition,
<table>
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<tr>
<th>CRITICAL MEASURES</th>
<th>WINNER</th>
<th>WHY?</th>
</tr>
</thead>
<tbody>
<tr>
<td>SURPRISE</td>
<td>F-16</td>
<td>HALF THE SIZE; MUCH LESS SMOKE.</td>
</tr>
<tr>
<td>NUMBERS IN THE AIR</td>
<td>F-16</td>
<td>3 TIMES MORE SORTIES PER $</td>
</tr>
<tr>
<td>MANEUVER TO FIRING POSITION</td>
<td>F-16</td>
<td>BETTER ACCEL; SAME MAX G; MUCH QUICKER ROLL; MUCH LONGER LEGS.</td>
</tr>
<tr>
<td>WEAPONS LETHALITY</td>
<td>SAME</td>
<td>SAME 20MM/IR MISSILE; AIM-7 DESTROYS SURPRISE AND HAS LOW PK.</td>
</tr>
</tbody>
</table>
each F-16 can fly about 1.4 times as many sorties per day as an F-15, due to its considerably lower failure rates and maintenance requirements. Thus, for every F-15 we forego, we can have three times as many F-16s actually facing the enemy.

In outmaneuvering the enemy, the F-16 has a moderate advantage over the F-15. The F-16 accelerates noticeably faster than the F-15, particularly in the all-important transonic region. In maximum g-turn performance, the two fighters are closely matched. But the F-16 can transition from one maneuver to another much more quickly than the F-15, due to its superior roll and pitch performance. As for range and combat endurance, despite its smaller size, the F-16 is considerably better; for instance, its air-to-air mission radius is at least 50% better than the F-15A.

Finally, in lethality given a firing opportunity, both fighters are essentially equal. Both carry the same gun and the same Sidewinder infrared missiles. The F-15 has an apparent advantage inasmuch as it also carries the Sparrow radar missile. On closer examination, this proves to be little or no advantage: in Vietnam, the Sparrow had a kill rate of .08 to .10, less than one third that of the AIM-9D/G — and new models of the Sparrow do not appear to have corrected the major reasons for this disappointing performance; even worse, locking-on with the Sparrow destroys surprise because of the distinctive and powerful radar signature involved.

In summary, in three of the four effectiveness areas critical to winning air-to-air battles, the cheaper F-16 is clearly more effective than the twice-as-expensive F-15, while in the remaining area the two are equal.

**Tank Effectiveness: M-1 Versus M-60A1**

To examine effectiveness in an area very different than air-to-air combat,
our second example compares tanks: the new $2.7 million M-1 against its predecessor, the $0.9 million M-60A1. The two will be compared in terms of six effectiveness characteristics critical to success in armor operations: operational mobility of complete tank battalions or brigades; numbers available at the point of engagement; machine gun effectiveness, particularly against close-in infantry threats; mobility in sudden tank-versus-tank or tank-versus-antitank firefights; time to kill multiple threats such as an enemy tank platoon; and crew survival in the face of enemy infantry weapons, mines and tank weapons. 10 Table IV summarizes the M-1 versus M-60 comparison in these six areas.

Operational mobility -- that is, the speed with which major tank units can be moved over distances of, say, 50 to 200 miles -- is addressed first because speed and surprise are the best guarantors of success and survival in tank operations. M-60 units will arrive at a distant objective considerably sooner than M-1 units mostly due to one critical advantage: M-60s break down between one quarter and one fifth as often as M-1s, based on operational tests and take about half as long to repair when they do break down. 11 A further impediment to fast M-1 unit moves over long distances is the need to refuel 40% more often then the M-60 (every 127 miles versus every 175 miles) and to carry along nearly twice as many fuel trucks. The fact that, when it is running reliably, the M-1 can average 25% better sustained speed than the M-60 (25 mph versus 20 mph over secondary roads in OT II at Fort Bliss) is not enough to offset the crippling effects of excessive breakdowns and high fuel consumption.

Next in importance is the number of tanks actually brought to bear on the enemy. Three M-60A1s can be procured for the cost of one M-1. But the
# TANK EFFECTIVENESS

**M-60A1 vs M-1**

<table>
<thead>
<tr>
<th>CRITICAL MEASURES</th>
<th>WINNER</th>
<th>WHY?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Mobility</td>
<td>M-60</td>
<td>M-1 must stop 5 times more often</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Range 1/3 less for M-1</td>
</tr>
<tr>
<td>Numbers Engaged</td>
<td>M-60</td>
<td>Buy 3 times more M-60s with twice the availability (85% vs 45%) =</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6:1 Shortfall</td>
</tr>
<tr>
<td>Machinegun Effectiveness</td>
<td>M-60</td>
<td>• M-1s cal .50 can’t be aimed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loader’s MG mount breaks</td>
</tr>
<tr>
<td>Firefight Mobility</td>
<td>?</td>
<td>• M-1 has higher ground pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Throws tracks in maneuvering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Has small edge in short dash accel</td>
</tr>
<tr>
<td>Rate of Kill vs Multiple Tanks at Real</td>
<td>M-60</td>
<td>• Loading slightly faster in M-60</td>
</tr>
<tr>
<td>Combat Range</td>
<td></td>
<td>• Battlesight accuracy same</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 63 rounds for M-60 vs 40 for M-1 (120 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High rate of failure with 120 mm caseless</td>
</tr>
<tr>
<td>Crew Survival</td>
<td>?</td>
<td>• 10 live firings vs. combat-loaded M-1 are grossly inadequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• M-1 better against heat from front 1800 but worse from rear; both</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Exhaust visible to IR at 5 km +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• More flammable hydraulic fluid (M-1)</td>
</tr>
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</table>

Table IV

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M-60 has an additional 2 to 1 advantage in daily availability for combat (85% versus 43%, based on OT II and OT III). This means that, for a given budget, we will bring to bear 6 times fewer tanks if we choose M-1s over M-60s. If we include the much larger number of M-1s that will be down for combat damage repairs, the M-1's effective force size may be less than 1/10th that of the M-60.

In machine gun effectiveness, the M-1 has some significant disadvantages. Due to the flat and very wide turret roof, fields of view (hatch open and closed) and machine gun fields of fire are poorer than the M-60 in the close-in zone where shoulder-fired infantry weapons are such a dangerous threat to tanks. Further, two of the three M-1 machine guns are nearly unusable: the commander's machine gun is, to quote the crews, "impossible" to aim due to quick power traverse and slow manual elevation controls; the loader's hatch machine gun has a mount that breaks in peacetime and is too flimsy to last in combat.

In firefight mobility, each tank has advantages and disadvantages. The M-60 is slightly better in mud and sand due to lower ground pressure (11 psi versus 13 psi). Over rough ground, the M-1 has a softer ride but has to restrict speed in maneuvering due to fear of track misguides (which can cause major damage to the final drives). The M-1 is slower in short dash acceleration due to the several seconds of lag inherent in turbine engines; however, in longer accelerations (say, beyond 100 feet) its higher horsepower gives it the advantage.

In time to kill multiple enemy tanks, the M-1 and the M-60 should be about equal since they have the same gun with the same accuracy and approximately the same time to aim. However, the M-1 may be one or two seconds
slower than the M-60's 7 seconds between aimed rounds due to the M-1's very cramped loader's station. In ability to sustain fire, the M-60 has a slight advantage with 63 rounds on board as opposed to only 55 for the M-1. When the M-1 converts to the larger 120 mm gun, its sustainability will fall to a clearly inadequate 40 rounds.

The final effectiveness characteristic, crew survival, can be assessed only on the basis of live firings against tanks loaded with the three principal hazards that kill crew members: ammunition, hydraulic fluid and fuel. For the M-1 and M-60, no clear comparison is possible due to the Army's long-standing tradition of not using live firings against combat-loaded tanks to test them for their greatest vulnerabilities.

The M-1 has significantly better crew protection than the M-60 against Sagger-size shaped charge antitank weapons from the front 180°, due to its Chobham armor which was specifically designed to defeat shaped charges. For the rear 180°, the M-1 has ordinary plate armor, slightly thinner than the M-60 and both tanks are easily penetrated by standard shoulder-fired infantry weapons such as the Soviet RPG-7. Which tank is more likely to burn given an RPG-7 hit from the rear 180° cannot be known without side-by-side live firings. Moving from infantry to tank threats, the most important Soviet tank cannon round, the high velocity solid projectile (APFSDS), penetrates both the M-1 and the M-60 -- a fact only recently admitted in open Congressional testimony. Given that both tanks are vulnerable to tank cannon rounds, only live firings tests can show which one is less likely to burn its crew. One point which weighs somewhat against the survival of M-1 crews is the heat of the turbine compartment and its jet exhaust: the M-1's heat can be seen with an infrared viewer at more than 5 times the typical visual detection distance.
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<tr>
<th>CRITICAL MEASURES</th>
<th>HOW DOES THE T-72 RATE?</th>
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<tr>
<td><strong>Operational Mobility</strong></td>
<td>• Breaks down 50% to 75% more often than M-60</td>
</tr>
<tr>
<td></td>
<td>• Slower than M-60 (15 MPH vs 20 MPH sustained)</td>
</tr>
<tr>
<td></td>
<td>• 1/3 less range than M-60</td>
</tr>
<tr>
<td><strong>Numbers Engaged</strong></td>
<td>• Produce 1500 to 2000 per year</td>
</tr>
<tr>
<td></td>
<td>• Deadline rate higher than M-60</td>
</tr>
<tr>
<td><strong>Firefight Mobility</strong></td>
<td>• Poorer braking but dash accel equal to M-60</td>
</tr>
<tr>
<td></td>
<td>• About same ground pressure</td>
</tr>
<tr>
<td></td>
<td>• Much harsher suspension</td>
</tr>
<tr>
<td><strong>Rate of Kill</strong></td>
<td>• Unreliable auto loader and much slower rate of fire than M-60</td>
</tr>
<tr>
<td></td>
<td>• 40 rounds vs 63 for M-60</td>
</tr>
<tr>
<td></td>
<td>• Penetrator probably steel (poor pyrophoricity)</td>
</tr>
<tr>
<td><strong>Crew Survival</strong></td>
<td>• Much thinner sides, top, bottom and rear than M-60</td>
</tr>
<tr>
<td></td>
<td>• Somewhat thicker glacis</td>
</tr>
<tr>
<td></td>
<td>• Very flammable when hit by DU penetrator</td>
</tr>
</tbody>
</table>

Table V
In machine gun effectiveness, both tanks have two reasonably effective machine guns, but the T-72 can carry only one-third the ammunition load of the M-60, a severe disadvantage in protecting the tank against infantry.

In firefight mobility, the T-72 has about the same ability to move in mud or sand as the M-60 but poorer rough ground mobility due to its harsher suspension and slower steering. Acceleration of the two tanks is about equal except for T-72 advantage in initial "jump" due to its more efficient, non-automatic transmission.

Rate of kill is probably the major Achilles heel of the T-72. The T-72 has the unreliable, crew-endangering autoloader first introduced in the now-failed T-64. The autoloader is claimed to have an 8 to 9 second reload cycle but the practical time between aimed shots is probably double this; even worse, when the auto-loader fails, which appears to be a frequent occurrence, the T-72 is probably not capable of better than 30 to 45 seconds between aimed rounds (since the crew no longer has a loader). In addition, the Soviet cannon projectile, which is steel as in the T-62 or possibly tungsten, is much less incendiary than the depleted uranium of the M-60 and M-1 penetrator. Nor can the T-72 sustain fire as well as the M-60, since it has only 40 rounds compared with the M-60's 63 rounds onboard.

Finally, crew survival in the T-72 is apparently nearly as poor as in the T-62, since the T-72 armor is as thin as the T-62 everywhere except on the front glacis plate, which has added an extra lumination. Live firing trials with the CAU-8 30 mm cannon of the A-10 showed the T-62 to be about twice as likely to burn or explode as the U.S. M-47, a tank slightly less well-armored than the M-60.
Thus, in five out of the six critical effectiveness criteria, the T-72 is deficient relative to the M-60. This is not strong support for the case that Soviet tank "quality" forces us to field a tank of unprecedented cost and complexity such as the M-1 -- especially when the M-1 shows no clear effectiveness advance over the M-60.

Does Soviet "Quality" Force Us to Adopt Complex, Expensive Solutions?
Example: The MiG-23

The four air-to-air effectiveness characteristics of the F-15 versus F-16 comparison can be used equally well to assess the MiG-23. Table VI presents a synopsis of this assessment.

The MiG-23 has considerably less ability to achieve surprise than the F-16 (or the MiG-21) because it is at least 50% larger. It is, in fact, nearly as big as an F-105. Even better for us, the MiG-23 is the first Soviet fighter that smokes heavily.

In numbers in the air, the MiG-23 represents a lesser threat than the MiG-21 insofar as its complexity forces the Soviets to lower production rates and poorer wartime sortie rates. On the other hand, the Soviets still produce at least five times more MiG-23s than we produce F-16s.

In maneuvering to firing position, the MiG-23 suffers its most severe disadvantage: its acceleration and turn capabilities are quite close to those of the F-105, a ground attack aircraft that makes no pretense of being an air-to-air fighter. In fact, the MiG-23 would probably lose a dogfight to an F-105 because the MiG's roll rate and endurance are inferior to the F-105.

In weapons lethality, the principal MiG-23 weapons are the same as the MiG-21: the 23 mm, a gun of considerably lower rate and velocity than the
<table>
<thead>
<tr>
<th>CRITICAL MEASURES</th>
<th>HOW DOES THE MiG-23 RATE?</th>
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| SURPRISE          | • ALMOST AS LARGE AS F-105  
                   | • SMOKES HEAVILY          |
| NUMBERS IN THE AIR| • 2/3 PRODUCTION OF MiG-21  
                   | • LOWER SORTIE RATE       |
| MANEUVER TO FIRING POSITION | • ACCEL AND TURN SIMILAR TO F-105  
                               | • ROLL RATE AND LEGS WORSE THAN F-105 |
| WEAPONS LEATHALITY| • RADAR LIKE F-4B         
                     | • GUN HAS LOW RATE AND POOR $v_0$  
                     | • USES OLD AIM-9 AND ???  
                     | RADAR MISSILE           |
U.S. armed, and the Atoll infrared missile, a copy of older Sidewinder models. In addition, the MiG-23 has a larger radar than the MiG-21, a radar that is perhaps most comparable to the non-lookdown pulse radar of the 1962 F-4B. Together with this the MiG-23 also carries radar missiles, of unknown capability. The Soviet radar/radar missile has never been tested in combat and, consequently, is unlikely to be any better than the disappointing F-4/Sparrow combination.

As in the case of the latest Soviet tank, the MiG-23's inferiority in three out of four categories again casts doubt on whether Soviet "quality" forces us to choose more complex, costly options. In fact, it appears that the MiG-23 is a substantially less dangerous opponent than the MiG-21.

One additional point is worth noting: for the T-72 and MiG-23, the one area in which both were superior to their U.S. counterpart was the area of numbers available in combat. In view of this, it is difficult to understand how buying fewer M-1s or fewer F-15s represents an appropriate response.

**Insights**

The foregoing analysis leads to some insights that, in retrospect, may seem obvious:

- There was and is no inherent dichotomy between quantity and quality.
- Instead, the issue has always been to distinguish what works in combat from what doesn't work.
- In the past, the weapons that were relatively costly or complex in their day have not usually worked well.
- This does not imply that all simple weapons work -- and we have many examples of how easy it is to field simple weapons that are ineffective, ranging from the .30 caliber carbine to the LAW.
- On the other hand, weapons that were remarkably effective in their day have almost always been relatively simple.

- We can't make progress in designing for superior effectiveness if we can't define it.

- To understand effectiveness -- that is, what works in war and what doesn't -- we have to spend much more time studying combat as it actually occurs. And we need to give much less credence to the hypotheses of technologists concerning how future combat might look.

To summarize, there is no inherent contradiction between "quality" and quantity in weapons. But our now-ingrained support of cost and complexity prevents us from using advanced, brilliantly-simplifying technology to make real progress in both "quality" and quantity of weapons.
Endnotes

1. Besides the "pea shooter" caliber, the AR-15 had two more strikes against it: it was privately designed outside the ordnance bureaucracy and it had the flimsy, mass-produced look of a Mattel toy.

2. About 85,000 AR-15s had been bought by ARPA during the period 1962 to 1964 and sent to Vietnam for combat evaluation.

3. This resulted in the superb reliability of the AR-15 being destroyed when the Army "militarized" it into the Vietnam standard issue M-16. That event and its tragic consequences in combat are beyond the scope of this discussion.

4. Even the critical step of fitting the Rolls-Royce Merlin engine to the underpowered early P-51s was bitterly opposed by the Wright-Patterson aircraft procurement bureaucracy.

5. The P-38 had a better combat record in the Pacific War for reasons that are worth understanding in designing new fighters today: in Europe, the P-38 had little or no sustained speed advantage over German fighters; in the Pacific, it had close to 100 mph advantage over the slow-cruising zero and thus achieved a dominant advantage in surprise bounces while avoiding maneuvering engagements.

6. Although radar fire control was available for the Soviet 85 mm and 57 mm batteries in Korea and Vietnam, as well as for the later ZSU-23-4, the preferred mode in combat against maneuvering attacks was optical aiming with radar range only.

7. Over half the Soviet submarine force consists of diesel-electrics and the Soviets, despite repeated predictions to the contrary, have continued to produce diesel-electrics to this day.

8. The derivation of these four effectiveness characteristics from the air combat experience of the last forty years is provided in more detail in a study and briefing by the author, Comparing the Effectiveness of Air-to-Air Fighters: F-100 to F-16.

9. This acceleration advantage has grown in the last few years with the thrust deterioration of the F-15 engine, a deterioration that has not been experienced in the F-16 version of the F-100 engine.

10. As in the case of air-to-air, these six effectiveness characteristics are based on detailed examination of U.S., German, and Israeli tank combat experience from 1940 to 1973, with particular emphasis on the views of successful armor commanders such as Wood, Patton, Balck, Guderian, Rommel and Tal. A discussion of this background is available in the author's briefing, Comparing the Effectiveness of Current Tanks.

11. M-1s in OT III required non-deferrable maintenance every 43 miles and each such repair lasted 2.6 hours, on average. Using the Army's more
artificial criterion of "chargeable" systems failures (as judged by a scoring conference), the M-1 failed every 99 to 105 miles in OT III; in the only side-by-side M-60/M-1 test (OT II at Fort Bliss), the M-60A1 was scored at 492 miles between systems failures.

12. Based on average mileage of 3.86 gallons per mile demonstrated in OT II and OT III; this includes idling time and a high percentage of travel on secondary roads.

13. Israeli field maintenance teams were able to turn around essentially all combat damaged M-60s in one to two days. M-1s are likely to take much longer because almost any hit on a Chobham armor panel will require depot-level repair and projectile damage to the gas turbine engine will require engine repair in the U.S.

14. A loader's hatch machine gun that worked, such as the one on the M-48A5, would be useful and an advantage over the M-60, which has only two machine guns.

15. Under the extreme time pressure to kill before being killed, neither tank will use ballistic computers and rangefinders (laser or optical) in combat because they cost on the order of 3 to 5 seconds in time. Instead, they will use the fixed battlesight, particularly since there is no need for ranging when engaging at less than 1000 meters. Both combat records and terrain measurements indicate that about 85% of engagements will be at less than 1000 meters. Indeed, about 50% will be at less than 500 meters.

16. There were a small number of live firings against a combat-loaded M-1, but they were designed to show success, not to probe for weaknesses.

17. It should be noted that the Sagger guided missile did not prove to be a major threat to Israeli tanks in the 1973 war, requiring an average of 80 firings per kill.

18. Arguments can be made either way. The M-1 might be more flammable because it has more ammunition high up in the tank, more fuel, and more of the Army's extremely (and unnecessarily) flammable hydraulic fluid. On the other hand, the M-1 may be less flammable because it has automatic fire-sensing extinguishers (which fail frequently) and an armored, hydraulically-operated door to separate the crew from most of the ammunition.

19. The T-72 is two or more tons heavier than the T-62 and appears to have added a supercharger to the T-62's diesel engine, changes that are not likely to increase reliability. Users complain that the T-62 has significant breakdowns every 100 to 125 miles; for details of Soviet tank unreliability, see Modern Soviet Armor by S. Zaloga.

20. In 1979, the Soviet T-64s in Eastern Europe were ordered to stop using the autoloader due to its tendency to feed parts of the gunner into the breech.
21. Acceleration and turn can be judged by calculating wing loading and thrust-to-weight from figures provided by Interavia or Jane's. Acceleration right at Mach 1 should be relatively better for the MiG-23 since it can sweep its wings aft, though in this position turn capability deteriorates even further.