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Intelligence Report

US-USSR Offensive Strategic Force Balance: Evolution and Measurement, 1965-1976

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US-USSR Offensive Strategic Force Balance: Evolution and Measurement, 1965-1976

Key Findings

The period since 1965 has been one of dramatic change in the strategic balance between the US and USSR and in the perception of that balance. It was widely recognized in the mid-1960s that the strategic balance was clearly in favor of the US because it led by such a wide margin in every simple numerical measure of strategic offensive power. Seeking to redress the imbalance, the Soviets began to improve and enlarge their forces, and by the mid-1970s they had achieved a rough strategic parity.

In the late 1960s and early 1970s many important technological innovations incorporated into both the US and Soviet nuclear arsenals complicated the perceptions of the strategic balance. Simple measures, such as the number of strategic nuclear delivery vehicles, were no longer as accurate a reflection of the strategic balance as they had been when one side had a clear margin in each category. Improvements in accuracy, throw weight, multiple warheads, and the capability to destroy hard targets required the introduction of a variety of more complex measures.

The Soviets, because of the dramatic growth in their intercontinental attack forces since 1965, now lead the US in several single measures of strategic power:

— number of delivery vehicles

— on-line equivalent megatonnage

— on-line missile throw weight

— lethal area for soft targets--i.e., the area that could be subjected to an overpressure of 103.4 kilopascals (15pounds per square inch) or more by their on-line force.

The US, on the other hand, continues to lead in:

— number of on-line missile RVs

— number of on-line missile RVs combined with bomber weapons

— on-line missile K factor, a measure of a missile's capability against a hard target.

Since the early 1970s it has become increasingly difficult to determine which country holds a strategic advantage.

CENTRAL INTELLIGENCE AGENCY
Directorate of Intelligence
November 1976

INTELLIGENCE REPORT

US-USSR Offensive Strategic Force Balance: Evolution and Measurement, 1965-1976

Preface

This paper presents an overview of the evolution of the US-USSR strategic balance from 1965 to 1976 in terms of the more commonly used quantitative measures of strategic power. The figures and analysis herein are intended to complement the analysis of the Soviet strategic forces as set forth in NIE 11-3/8 by providing an historical background. The paper is not intended to present an exhaustive study of the evolution, but only to describe the more significant developments.

The report also provides a technical explanation of these measurements. The definitions and mathematical formulas are those commonly used by analysts to describe and quantify US and Soviet strategic forces. The definitions in the paper are also consistent with those in the NIE.

With the exception of ABMs, it is the strategic offensive systems that have been the focus for measuring strategic power and the object of arms control consideration, and it is this category of weapons that is examined in this paper. The report does not address civil defense, antisubmarine warfare, or air defense, although they all influence perceptions of the overall strategic balance.

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Factors Determining Evolution of US and Soviet Strategic Forces

Objectives and Perceptions

Differing strategic objectives and perceptions have had an effect on the respective forces of the US and the USSR and on the strategic balance.

The US has built and deployed strategic nuclear forces to accord with the general concept of strategic deterrence--the ability to survive a surprise attack and retaliate with devastating means against the Soviet population, industry, and military. There has been an evolution of this general concept, however, with the emphasis now on attacks against the military and industrial base rather than against the population.*

The US has perceived a Soviet surprise attack as the main threat to the effectiveness of its policy of

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* The evolution of the concept of strategic deterrence can be illustrated from the Annual Defense Department Reports of two Secretaries of Defense. In his January 1965 Posture Statement, Secretary of Defense Robert McNamara presented what he felt would represent assured destruction: "It seems reasonable to assume that the destruction of one-quarter to one-third of its population and about two-thirds of its industrial capacity would mean the elimination of the aggressor as a major power for many years. Such a level of destruction would certainly represent intolerable punishment to any industrial nation and thus should serve as an effective deterrent." He also said that the offensive attack forces could limit damage from counterstrikes "by attacking enemy delivery vehicles on their bases or launch sites, provided that our forces can reach them before the vehicles are launched at our cities."

In the Annual Defense Department Report for FY 1977, Secretary of Defense Donald Rumsfeld presented this condition for credible deterrence: "The United States must have some minimum force which can survive even a well-executed surprise attack in adequate numbers to strike back with devastating force at an enemy's economic and political assets." He also indicated a need for flexibility in US forces and stated that "coverage of some enemy silos, airfields, or submarine bases on a second strike should not be ruled out."

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deterrence and has developed, deployed, and operated its forces accordingly. To counter a surprise attack and allow for the possibility that in a nuclear war a given category of weapons might not be effective, the US has adopted the concept of a synergistic Triad of ICBMs, SLBMs, and heavy bombers. The US has operated about half of its SSBN force at sea at any given time and maintained a large fraction of its bomber force on alert. Should one element of the Triad fail, the other elements could still be expected to respond effectively. Maintaining the Triad at a high level of alert also means that the Soviets could not expect to launch a successful surprise attack against all components simultaneously.

USSR. The Soviets, too, view deterrence as a primary objective for their strategic nuclear forces. Certainly during the 1960s one of their primary goals was to attain a credible deterrent posture by catching up with the US in nuclear delivery capability. In addition, the Soviets are aware that deterrence could fail, and they seek to develop a force which could fight and win a nuclear war if deterrence fails. Concern for the combined threat of the US, its Western allies, and China has also influenced Soviet views of deterrence.

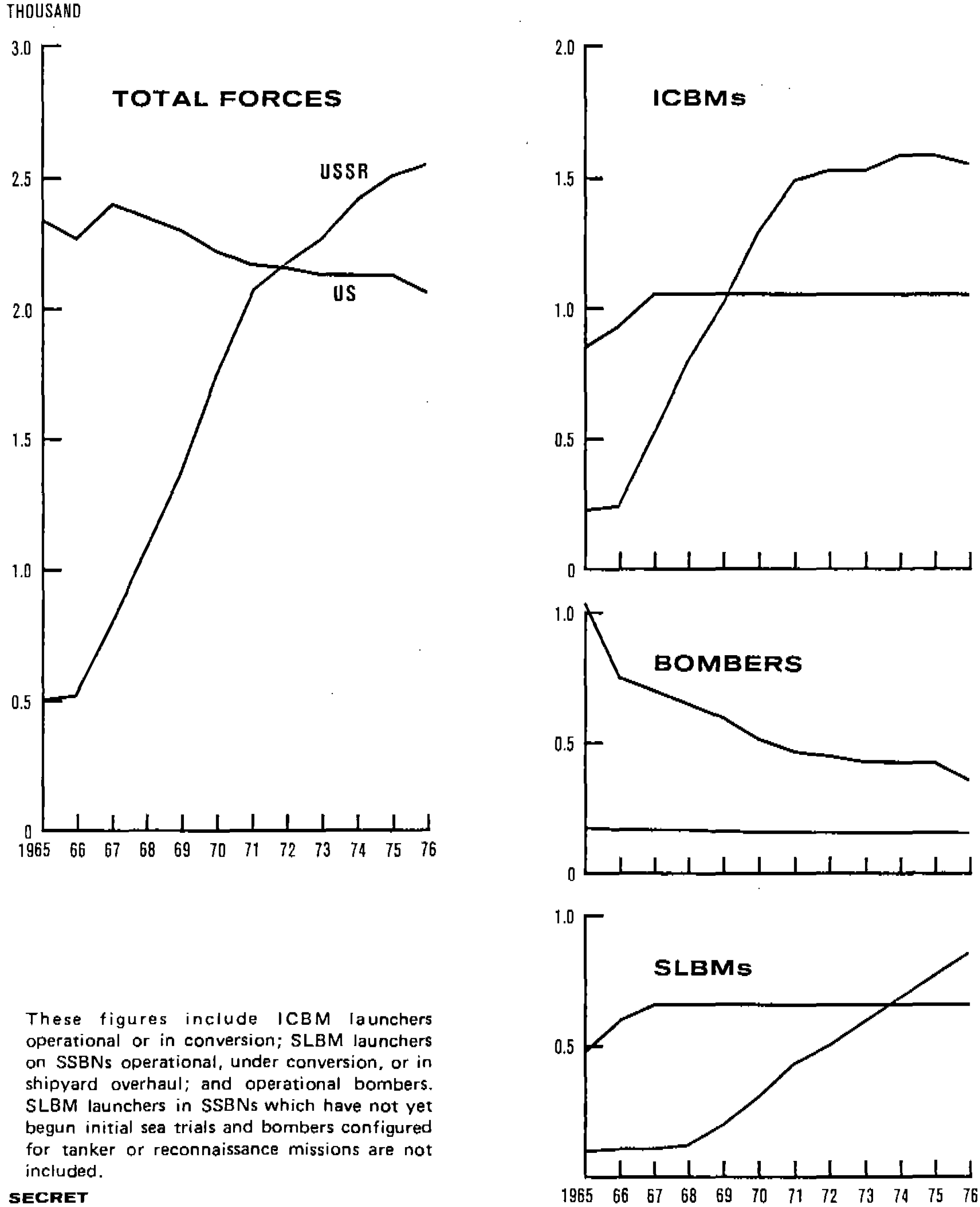
Soviet doctrine allows for the possibility of surprise attack but implicitly rejects the idea that war is likely to begin like a "bolt from the blue." The Soviets apparently believe that they would receive adequate strategic warning of a US attack. Only a small fraction of the Soviet ICBM force is believed to be maintained at full readiness, no more than 15 percent of the SSBN force is normally deployed on patrol, and bombers are not dispersed and thus are vulnerable to a surprise attack. Technical disparities such as the estimated short lifetime of Soviet guidance components may account for the different methods of operation. It is also possible that the Soviets think their alert ICBM and SLBM force provides sufficient survivability to guarantee deterrence of a US first strike.

Weapons Development and Deployment

As a result of differences in objectives and perceptions, US and Soviet forces--ICBMs, SSBNs, and bombers--differ in composition and size *(see Figure 1)*.

FIGURE 1

COMPOSITION OF US AND USSR INTERCONTINENTAL ATTACK FORCES, 1965-1976



These figures include ICBM launchers operational or in conversion; SLBM launchers on SSBNs operational, under conversion, or in shipyard overhaul; and operational bombers. SLBM launchers in SSBNs which have not yet begun initial sea trials and bombers configured for tanker or reconnaissance missions are not included.

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The ICBM force has grown to be the largest single component in each country's strategic arsenal in numbers of delivery vehicles. Bombers continue to be a much larger fraction of the US inventory, however, than they are of the Soviet force. The once small Soviet SLBM force is growing rapidly as the Soviets continue to build SSBNs at the rate of about six per year.

The number of delivery vehicles in each of the three components of the US strategic force has changed little since the late 1960s, but there have been improvements to the force, such as the introduction of MIRVs in 1970, that have substantially altered other quantitative measures. The number of US ICBMs and SLBMs had leveled off by 1967, while retirement of older US bombers continued until about 1970.

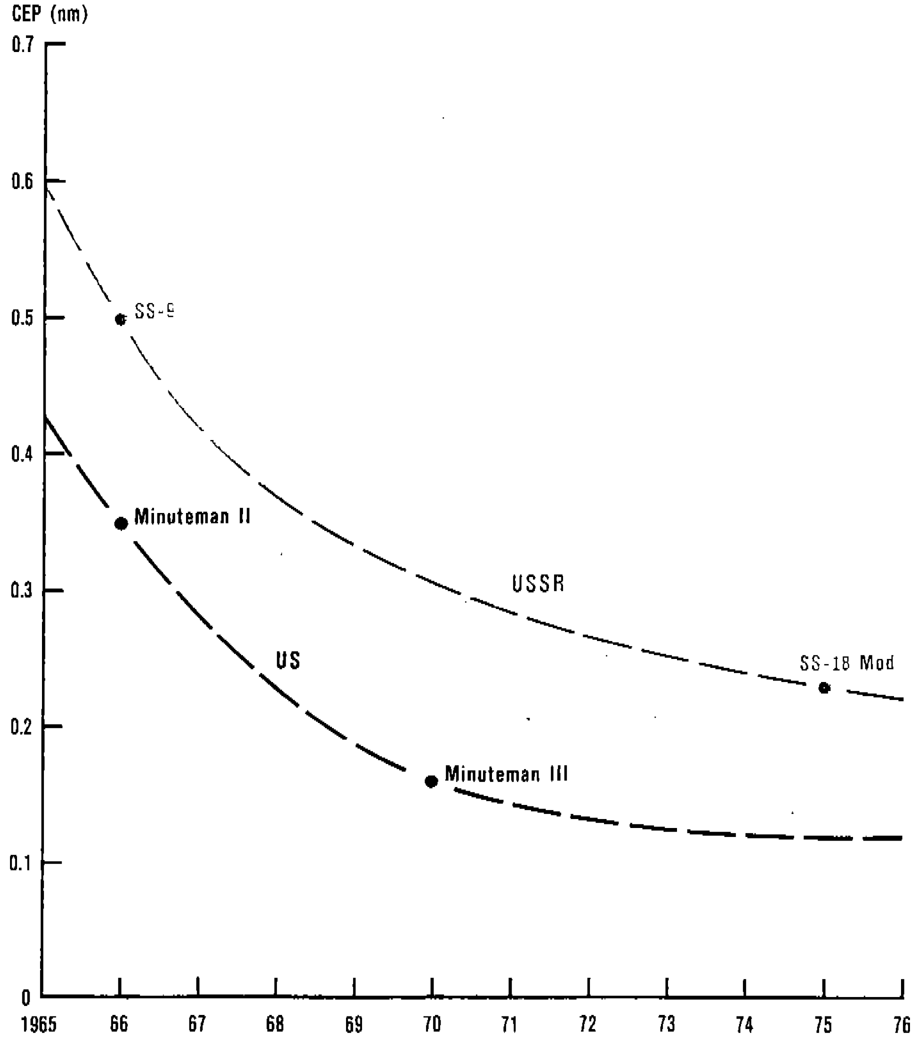
The Soviets, on the other hand, have greatly increased the number of delivery vehicles in their strategic force since the late 1960s. Most of this growth was in ICBMs through the early 1970s. The introduction of MIRVs, some five years after the US, added to the growth in ICBM reentry vehicles. More recently, the growth of Soviet strategic forces has been in SLBMs. The Soviet bomber force has remained basically unchanged throughout the period. The table on page 12 summarizes the major developments in weaponry during this period.

Technological advances also have had an effect on our methods of assessing the strategic balance. For the US, developments such as improved missile accuracy *(see Figure 2)* resulted in a greater emphasis on the qualitative aspects of weapons. On the other hand, Soviet emphasis on the number of launchers and on the size of ICBMs has given the USSR the lead in some quantitative measurements of the strategic balance.

Given the diversity of force developments, single measures, such as the number of nuclear delivery vehicles, have even less meaning in assessing the strategic balance than they had in the past. Improvements in missile accuracy and yield have provided the US and the USSR with the capability to destroy a portion of their opponent's silo-based ICBM forces, introducing a further complexity to assessments of the strategic balance.

FIGURE 2

IMPROVEMENTS IN ICBM ACCURACY, 1965-1976



Circular error probable (CEP) is defined as the radius of a circle, centered on the intended target, within which 50 percent of the reliable weapons are expected to fall. The other 50 percent are expected to fall outside the circle but within 3 1/2 CEPs of the target.

The curves shown here are plotted using the estimated potential accuracy when the ICBM system became operational for the first time. Only the most accurate system has been used when more than one system has become operational at about the same time. Systems with CEPs larger than those already deployed are not considered.

For the US, the curve has been extrapolated from 1970 using the accuracy improvement programed for the Minuteman III.

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US and USSR: Deployment Landmarks for Intercontinental Offensive Forces

United States

ICBM

1966 - First Minuteman II

1967 - Force of 1,054 ICBMs--1,000 Minuteman, and 54 Titan II missiles

1970 - First MIRVed ICBM, the Minuteman III

SLBM

1967 - Force of 656 Polaris missile launchers

1970 - First MIRVed SLBM, the Poseidon

Bombers

1973 - SRAM missile (to improve the capability of the B-52 force)

Soviet Union

ICBM

1966 - The SS-11, the Soviet counterpart to the Minuteman I

- The SS-9, Soviet heavy ICBM

1969 - Solid-fuel ICBM, the SS-13

1970 - First MRV, the SS-9 Mod 4

1970 - Soviets surpass US in number of deployed ICBMs

1974-75 - New generation of ICBMs (SS-17, SS-18, SS-19), including the first Soviet MIRVed missiles

SLBM

1969 - SS-N-6 aboard Y class SSBN

1973 - 4,200-nm SS-N-8 aboard D class SSBN

1974-75 - Soviets surpass US in number of SLBM launchers

The first ICBMs--the Soviet SS-6, SS-7, and SS-8, and the US Atlas and Titan--were large in both warhead yield and size. In fact, the Titan II, initially deployed in 1963, could deliver roughly twice the yield of any Soviet ICBM until 1966. In expanding its ICBM force with a second-generation missile beginning in 1963, however, the US chose a much smaller, more accurate, cheaper ICBM--the fast-reaction, solid-propellant Minuteman I.

In 1966, the Soviet SS-11 Mod 1 became operational. This liquid-fueled missile is comparable to the Minuteman I in yield and throw weight but is substantially less accurate than the Minuteman II, which also became operational that year. The Soviets during this same period developed the much larger SS-9 ICBM and began to deploy it extensively. We do not know whether they did this to compensate for their technological inferiority in missile accuracy, to offset any advantage the Titan II gave the US, or to acquire some counterforce capability.

Measuring the Strategic Balance

Concepts

The impact of the differing force composition, growth rates, and technical characteristics of US and Soviet forces is reflected in the measures used to evaluate the strategic balance from 1965 to 1975. Three categories of measures are used--static, dynamic, and quasi-dynamic.

Static measures are the simplest and most common means used to describe the strategic balance. A static measure sums a single weapon characteristic, such as the number or yield, for the entire force. It does not in any way measure the capability of a weapon against a specific target.

The most complex category is the dynamic measure, which involves calculating not only the weapon characteristics but also the effect of using the weapons in an attack. Dynamic measures consider a particular application of each weapon (e.g., destruction of hard targets or destruction of population) and the conditions under which it is used (e.g., surprise attack or retaliation). These measures are particularly sensitive to underlying assumptions about weapons effects. They can be used, for example, to estimate the number of missiles or warheads remaining on each side after a nuclear exchange. They are of little use in predicting the outcome of a war, however, because they do not consider some important operational factors, such as the timing of all elements of an attack.

Two important dynamic measures--fatalities and damage, and number of surviving silos--are discussed in this paper, but calculations are not presented. During the period since 1965, so many factors--assessments of target vulnerability, targeting assumptions, and types, yield and accuracy of weapons--have changed that it would be difficult to define a consistent method of assessment for the entire period.

Between these extremes of measurement are the quasi-dynamic measures. Like dynamic measures, these combine weapon system characteristics in a calculation which is based on a hypothetical force interaction. They do not, however, consider an enemy's specific target structure in evaluating force capability. Rather, a single nominal value, such as hardness, is employed to assess the vulnerability of a class of targets. The value of each weapon is weighted according to its capability to destroy the target. The quasi-dynamic measure of a force is the aggregate of these weighted values for all weapons employed in the attacking force.

The significance of and requirement for certain static, dynamic, and quasi-dynamic measures have changed over time. In intelligence estimates, some measures (such as silo destruction capability) have been applied only to future forces because they did not reflect a capability then in existence. For the same reason--changed weapon characteristics--the measures used today are not always applicable to an historical assessment of past forces.

In measuring strategic balance, operational status determines which systems are included. In this paper, the total strategic attack force--all operational systems, ICBM and SLBM launchers under conversion, and SSBNs in shipyard overhaul--is used to determine the number of delivery vehicles. For all other measures, however, only the on-line force, which excludes launchers in conversion and SSBNs in shipyard overhaul, is used because at any given time only on-line weapons have military potential.

Static Measures

Number of Delivery Vehicles. The issue of whether the US or the USSR had the greater number of strategic nuclear delivery vehicles--ICBMs, SLBMs and bombers--received considerable public attention in the US during the "missile gap" discussions in the early 1960s and again with respect to SALT in the early 1970s. The US superiority of the mid-1960s disappeared *(see Figure 1)* as the Soviets rapidly expanded their ICBM and later their SLBM forces. The adequacy of strategic forces, however, cannot be evaluated simply by counting the number of nuclear delivery vehicles.

Number of Weapons. A weapon is capable of attacking a single target, and the number of weapons always has been an important measure because it sets a limit on the number of targets that can be attacked.* Weapons vary in size and capability, however, and it is impossible to translate this measure into a comprehensive indicator of a force's potential to destroy its targets. The number of weapons that could be delivered upon the Soviet Union or the US became a particularly important issue during the late 1960s when the deployment of anti-ballistic missiles was under consideration.

The introduction by the US of MIRVs in the early 1970s caused increased emphasis to be placed on the number of weapons as a measure. The capability of a bomber to carry multiple weapons did not have the same impact, because bombers are less effective than missiles for attacking ICBM silos and other time-urgent targets. Furthermore, all of a bomber's weapons can be destroyed by a single defensive attack on the bomber.

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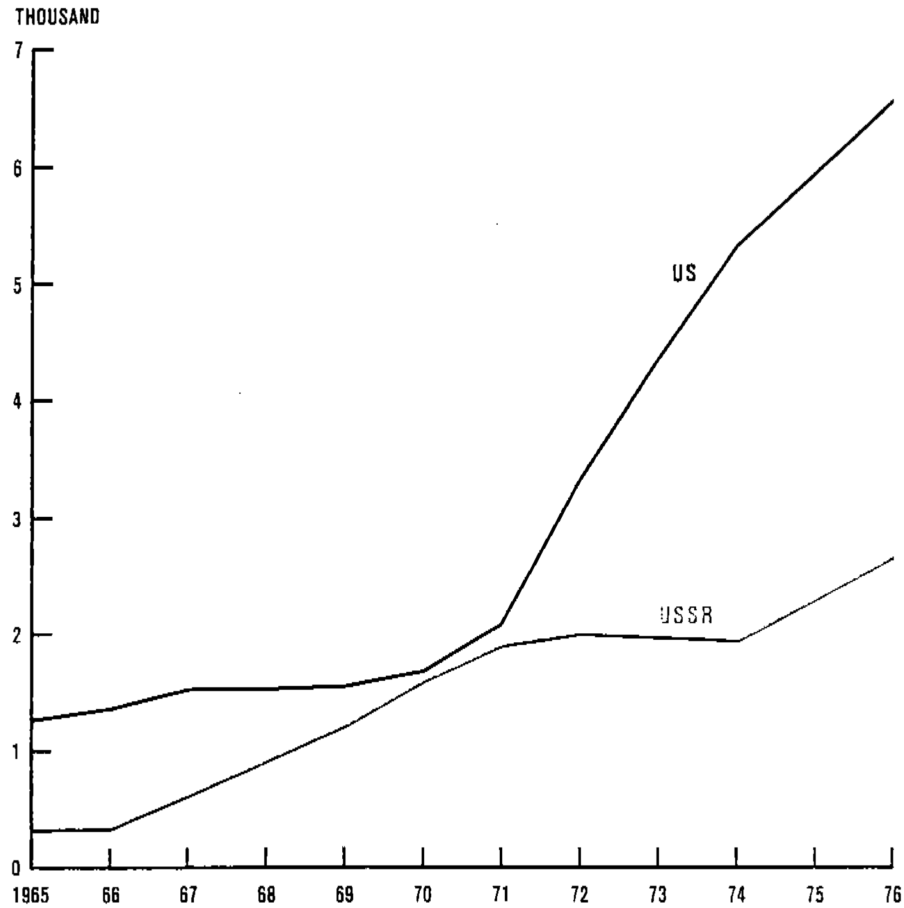
* In counting numbers of weapons, MRVs which can attack only a single target are counted as a single weapon.

FIGURE 3

ON-LINE MISSILE RVs FOR INTERCONTINENTAL ATTACK, 1965-1976



Missile payloads composed of MRVs are counted as one RV. These include Polaris A-3, SS-9 Mod 4, SS-11 Mod 3, and SS-N-6 Mod 3.

US missile RV loadings are assumed as follows: Minuteman III, 3 RVs; Poseidon, 10 RVs.

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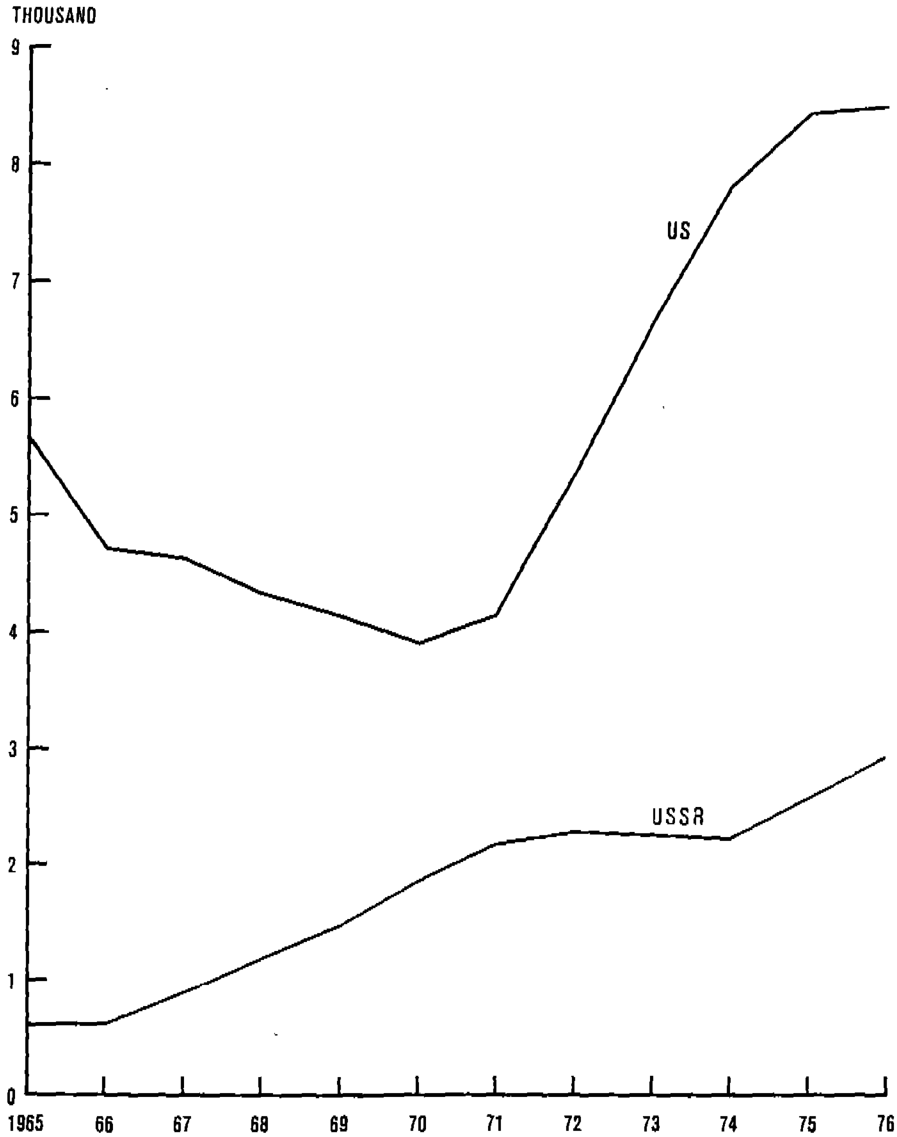
FIGURE 4

ON-LINE MISSILE RVs AND BOMBER WEAPONS FOR INTERCONTINENTAL ATTACK, 1965-1976



Missile payloads composed of MRVs are counted as one RV. These include Polaris A-3, SS-9 Mod 4, SS-11 Mod 3, and SS-N-6 Mod 3.

US missile RV loadings are assumed as follows: Minuteman III, 3 RVs; Poseidon, 10 RVs.

Bomber weapon loadings are assumed as follows: Bear, 1 ASM or 3 bombs; Bison, 2 bombs; B-47, 4 bombs; B-58, 5 bombs; B-52, either 4 bombs or 4 bombs and 6 SRAMs.

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Figures 3 and 4 show, respectively, the number of US and Soviet missile RVs and the total number of weapons in both countries' arsenals, including those carried aboard bombers. The charts show how Soviet growth in missile launchers has been overshadowed by the US development and deployment of MIRVs in the seventies. Because of the large US bomber force the Soviets have never really approached the US in total number of weapons, with the disparity growing wider during the first half of the 1970s.

Megatonnage. The energy released from a detonated nuclear weapon is expressed in terms of kilotons or megatons of TNT--the equivalent TNT required to produce the same amount of energy. The megatonnage of a force is the aggregate yield of that force's arsenal. Because most older missiles lacked the accuracy and yield to be effective against hardened targets and could be evaluated only by their capability to destroy unprotected targets, total force megatonnage came into usage as a measure of capability against unhardened or soft area targets, including urban areas.

Equivalent Megatonnage. Equivalent megatonnage (EMT) is a crude measure used to relate the destructive capability of a weapon to that of a one-megaton weapon. The destructive capability of a given weapon does not increase in direct proportion to its yield. Megatonnage per weapon is therefore adjusted (upward for yields less than 1 MT; downward for yields greater than 1 MT) to EMT to provide a better comparative measure of force potential against area targets *(see Figure 5)*.

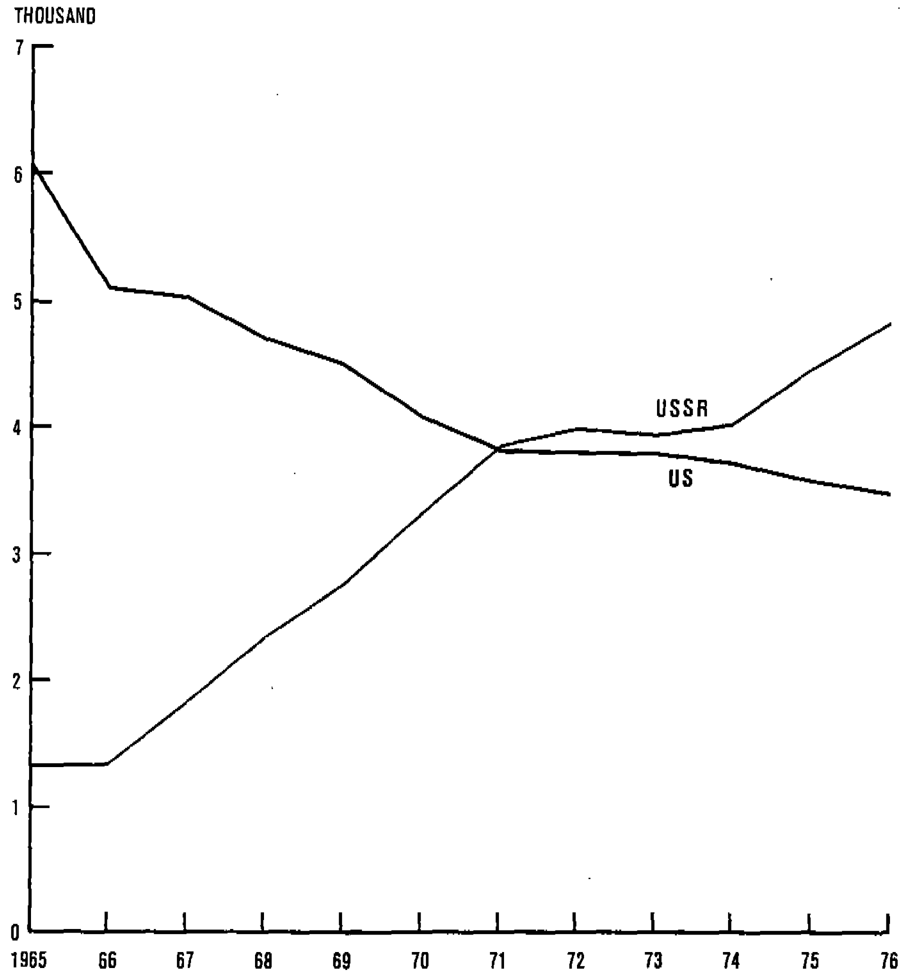
EMT was used throughout the 1960s and into the early 1970s as a measure of the deterrent capability of US forces. By the early 1970s, the Soviets had overcome the US advantage in EMT, and with their deployment of fourth-generation ICBMs, they continue to have an advantage.

Throw Weight. Throw weight is the total weight of the weapon-associated part of the missile; it may include the weight of warheads, decoys, and the postboost vehicle. Throw weight is the fundamental measure of the maximum payload that can be delivered on a target.

The introduction of MIRVs and the prospect of long-term strategic arms agreements limiting the number of delivery vehicles have increased the importance of mis-

FIGURE 5

ON-LINE EQUIVALENT MEGATONNAGE FOR INTERCONTINENTAL ATTACK, 1965-1976



Because a weapon's power is dissipated in proportion to area, its effectiveness is a function of its yield raised to the two-thirds power. In addition, soft area targets are generally distributed unevenly over a large circular area. Thus there tends to be wasted capability in large-yield weapons. Any crude measure of the destructive capability of a weapon owing to overpressure against soft area targets—such as equivalent megatonnage (EMT)—must adjust for both the physical phenomena and the target structure. The EMT of a weapon is defined as the yield raised to the one-half power for weapons having a yield greater than one megaton and the yield raised to the two-thirds power for those of less than one megaton.

EMT is not a good measure for accurately evaluating the full capability of small-yield weapons (100 kilotons or less). In this range, overpressure is not as important in determining the area of lethality as other sources of destruction released when a nuclear weapon is detonated. Another drawback to the EMT measure is that it is derived from the optimal targeting of US cities; targeting to destroy Soviet cities would result in a different value for EMT.

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sile throw weight as a static indicator. The Soviets have chosen to develop missiles with greater throw weight than those of the US. Some Western observers are concerned with the possible impact of this asymmetry on future force potential--especially since improvements in RV packaging technology and miniaturization of guidance systems can result in greater payloads for MIRVed missiles. Others contend that while throw weight can be important, there is a level beyond which additional throw weight is unnecessary to accomplish targeting objectives. Both sides to this debate acknowledge, of course, that each missile's capability is limited by factors other than throw weight, such as accuracy and yield.

One drawback in using throw weight as a measure of force potential is that no comparable measure exists for bombers. Various methods have been proposed for estimating the missile throw-weight equivalent of a bomber's payload. The simplest is to use the total weight of the average operational weapon load which the bomber is to carry to intercontinental range. (For an air-to-surface missile this would include the entire weight of the missile.) The aggregate measure for a force would then include both missile throw weight and bomber payload.

FIGURE 6

ON-LINE MISSILE THROW WEIGHT FOR INTERCONTINENTAL ATTACK, 1965-1976

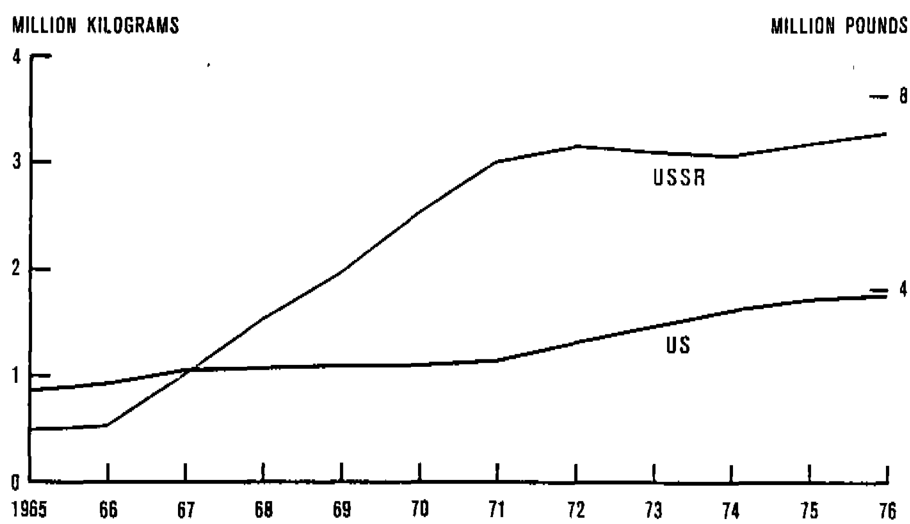

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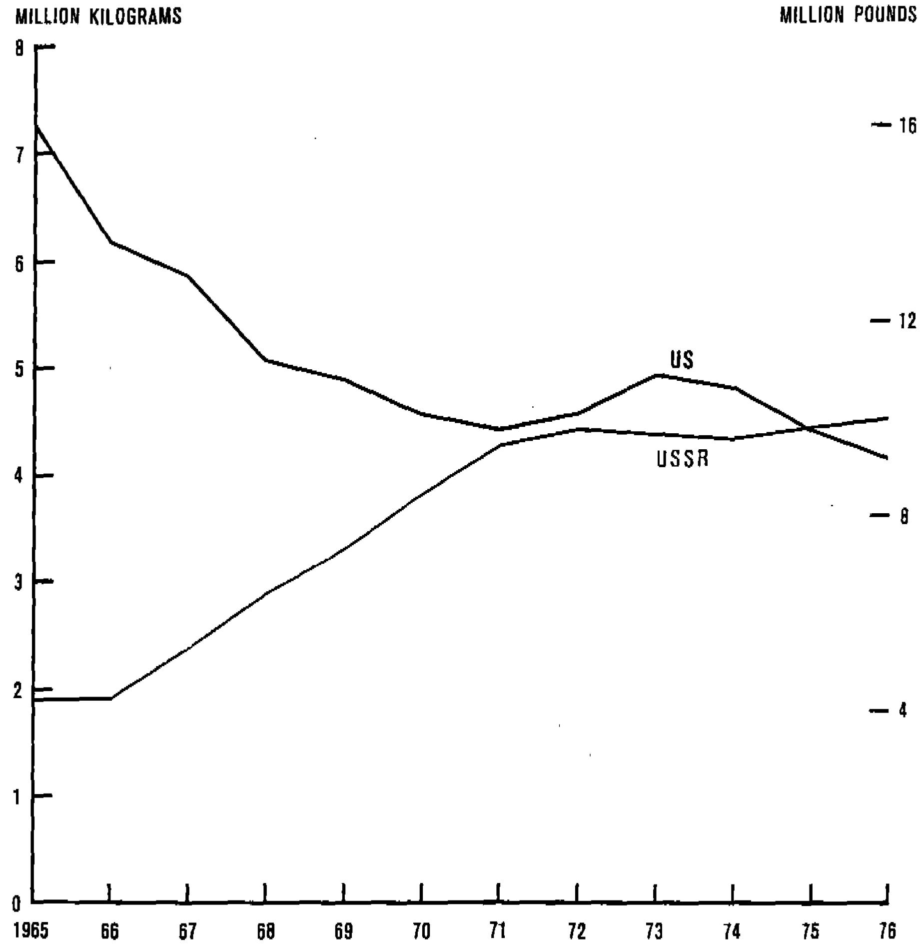
FIGURE 7

ON-LINE MISSILE THROW WEIGHT AND BOMBER PAYLOAD FOR INTERCONTINENTAL ATTACK, 1965-1976



Average bomber loadings are assumed as follows:

B-47	4 bombs @ 1,068 kg	4,272 kg
B-58	5 bombs @ 1,068 kg	5,340 kg
B-52 D	4 bombs @ 1,068 kg	4,272 kg
B-52 G/H	4 bombs @ 1,068 kg and 6 SRAMs @ 1,000 kg	10,272 kg
Bear	1 ASM @ 11,364 kg	11,364 kg
Bear	4 bombs @ 1,361 kg	5,444 kg
Bison	2 bombs @ 2,359 kg	4,718 kg

In this loading calculation, short-range attack missile (SRAM) loadings for the B-52 are limited to the numbers actually procured.

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Figure 6 demonstrates that the Soviets have held a wide margin in missile throw weight since the late 1960s. When bomber payload is added to the measure, however, a rough balance has existed since the early 1970s, as shown in Figure 7.

K Factor. Two weapon characteristics, yield and accuracy, fundamentally determine its capability to destroy a target hardened to some defined level. The K factor expresses the relationship between these two characteristics. Hard-target capability increases more rapidly with improved accuracy than it does with increased yield.

The K factor is the yield raised to the 2/3 power and divided by the squared value of the circular error probable (CEP). As Figure 8 shows, the US lead in this measure grew throughout the first half of the 1970s as more accurate missiles were deployed.

Quasi-dynamic Measures

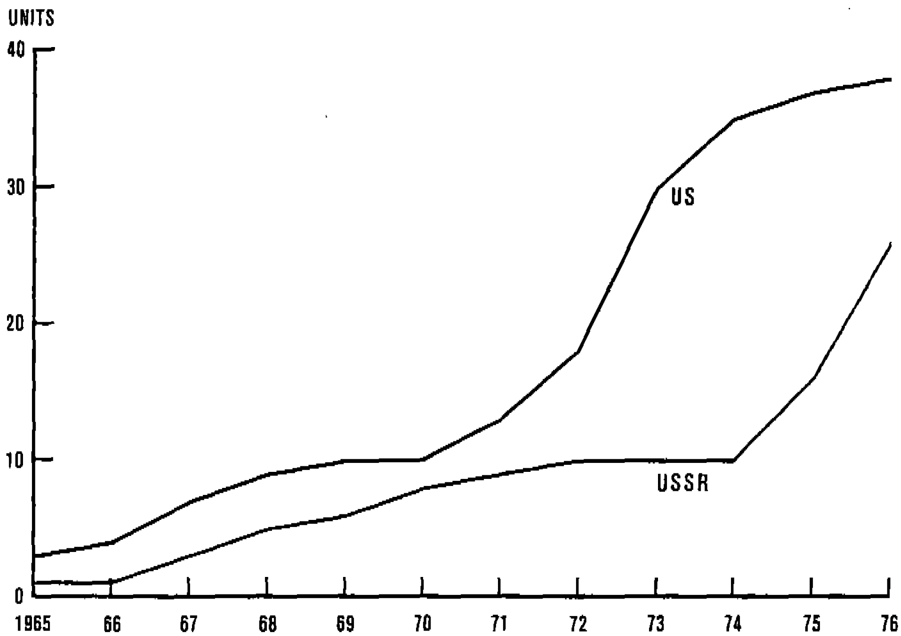
Lethal Area. Lethal area is a measure which assesses the comparative destructive potential against area targets. A weapon's lethal area is that area, in square nautical miles, that would be subjected to some nominal level of vulnerability. Targets within this area which were not hardened to withstand the defined overpressure would be destroyed. The lethal area created by an entire force, then, is the aggregate of that area for all weapons in the arsenal. For example, the lethal area created by overpressure of 103.4 kilopascals* (15 pounds per square inch) provides a rough measure of force effectiveness against urban and industrial targets, military facilities, and troop concentrations. Reinforced buildings and most industrial facilities would be destroyed.

Figure 9 shows that in 1970 the Soviets began to surpass the US in the total lethal area that could be devastated at 103.4 kPa (15 psi). The US capability has de-

* A kilopascal (kPa) is a term used in the metric system as a measurement of pressure. It is defined as the force of one newton acting on an area of one square meter. (A newton is the force required to accelerate one kilogram mass one meter per second.) The factor used in converting from pounds per square inch is 6.89476 kPa=1 psi.

FIGURE 8

ON-LINE MISSILE K FACTOR, 1965-1976



The K factor for a single weapon is defined as the yield raised to the two-thirds power divided by the squared value of the CEP. The K factor expresses the relationship between yield and CEP in computing the probability a weapon could destroy a hardened target. The probability of destroying a hardened target grows as K increases. The K factor for an entire force is simply the sum of the individual K factors.

To avoid giving too much significance to weapons having small yield or high accuracy, the definition is modified so that a yield less than 0.2 megatons is raised to 0.8 power rather than the two-thirds power, and no weapon can have more than 148 units.

Mathematically, the adjusted K factor presented here could be expressed as:

$$K = \sum_{i=1}^{n} n_i k_i$$

where n is the number of weapon types, n_i is the number of weapons of type i, and

$$k_i = \begin{cases} k_i^* & k_i^* < 148 \\ 148 & k_i^* \geqslant 148 \end{cases}$$

$$k_i^* = \begin{cases} y_i^{2/3} / c_i^2 & y_i \geqslant 0.2 \\ y_i^{0.8} / c_i^2 & y_i < 0.2 \end{cases}$$

where y_i is the yield of weapon type i in megatons and c_i is the CEP of weapon type i in nautical miles.

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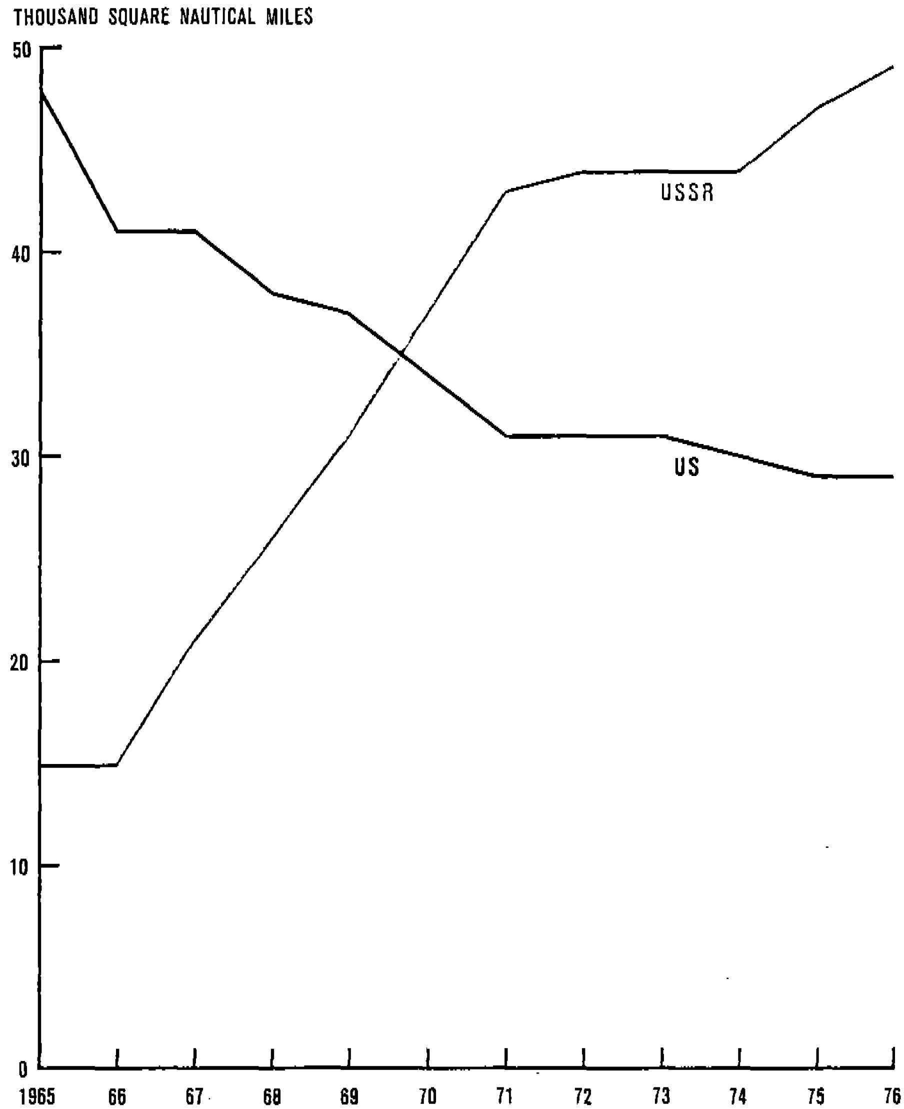
FIGURE 9

LETHAL AREA AT
103.4 KILOPASCALS OF OVERPRESSURE, 1965-1976



Lethal area is the total area, in square nautical miles, that could be devastated if all weapons in a force were detonated. The level of vulnerability used—103.4 kPa (15 psi)—is sufficient to destroy reinforced buildings and most industrial facilities. If n is the number of weapon types, n_i is the number of weapons of type i, and a_i is the lethal area of weapon types i for 103.4 kPa (15 psi), then the total area would be given by:

$$LA = \sum_{i=1}^{n} n_i a_i$$

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clined over time primarily because of the phaseout of older bombers. Both the US and the USSR, however, possess the potential to devastate more than 29,000 square nautical miles of the opponent's country at this level of vulnerability.

Lethal area has some drawbacks as a measurement of force effectiveness. It overstates actual capability by ignoring the overlapping weapon effects which occur when several weapons are detonated in the same geographic area, and it does not consider the wasted capability resulting from the irregular shape of real target areas. In addition, the lethal area measure proves inadequate in a force-wide comparison because some weapons in an arsenal are designated for point targets, such as missile silos, rather than area targets.

Counterforce Index. A counterforce index measures the potential of an attacking force to destroy point targets hardened to some nominal value. The most elementary product of this measure would be the expected number of targets of a given hardness that could be destroyed by the entire force. This is calculated by determining the probability of destruction for each type of weapon and summing these probabilities over the entire force. Fratricide considerations* and operational demands, however, could limit the number of weapons that would actually be allocated to each target in a strike. The counterforce measure, therefore, may overestimate the potential of a force.

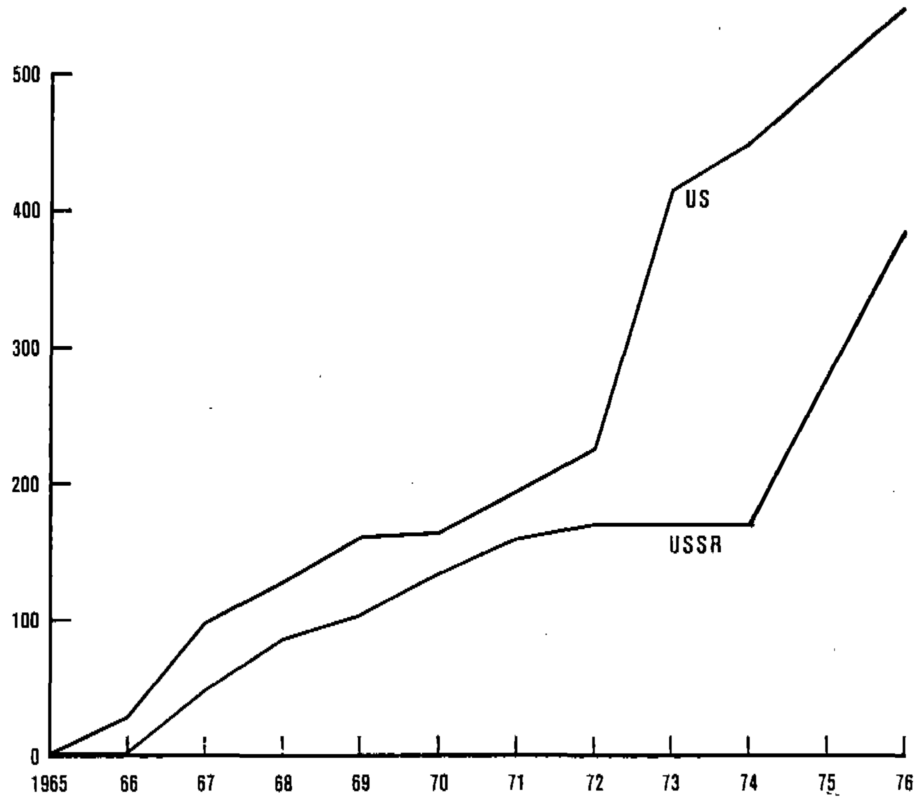
To represent more realistically a force's potential for destroying hardened targets, the counterforce index presented in this paper considers only effective weapons. An effective weapon system is defined as one which has a 50-percent probability of destroying a given target by employing no more than two weapons against it.

The calculations used here *(see Figure 10)* assume a nominal target hardness of 6,895 kPa (1,000 psi). This is the hardness generally attributed to the Minuteman silo throughout the late 1960s and the early 1970s. Figure 10 shows that, while both US and Soviet hard-

* The term fratricide refers to the destruction or degradation of performance that occurs to a warhead by the detonation of a nearby warhead.

FIGURE 10

ON-LINE COUNTERFORCE INDEX FOR ICBM ATTACK, 1965-1976



The counterforce index presented here depicts the expected number of targets, hardened to 6,895 kPa (1,000 psi), which could be destroyed with at least a 50-percent level of probability.

To calculate this index:

- for all weapon types that have a kill probability greater than 50 percent, the probabilities are summed;
- for all weapon types that have a compounded kill probability for two weapons against a single target greater than 50 percent and a kill probability for one weapon of less than 50 percent, the compounded kill probabilities for two weapons are summed.

Mathematically, this can be represented as:

$$CI = \sum_{i=1}^{n} V_i \qquad \text{where: } V_i = \begin{cases} n_i p_i & p_i > 0.5 \\ (n_i/2)\,[1-(1-p_i)^2] & 0.293 < p_i < 0.5 \\ 0 & p_i < 0.293 \end{cases}$$

where n is the number of weapon types; n_i is the number of weapons of type i; and p_i is the kill probability of a single weapon of type i. A compounded kill probability of 0.5 or greater for two weapons requires a single shot probability of at least 0.293.

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target capabilities are increasing, the US maintains a large lead. This is because of the introduction of the more accurate Minuteman III and the improvements to the accuracy of the Minuteman II.

The counterforce index presented here does not provide a historical perception of silo vulnerability, nor does it compare hard-target capabilities to perceived requirements; it only demonstrates trends in weapons potential. This measure may be particularly misleading when evaluating historical data, as most Soviet silos and some US silos extant or under construction from 1965 to 1976 are estimated to be less than 6,895 kPa (1,000 psi) hard. Nevertheless, the introduction of MIRVed missiles in the early 1970s, as well as improved weapon accuracies, has made the counterforce index a more meaningful measure in evaluating the strategic balance.

Dynamic Measures

Number of Surviving Silos. The number of hardened silos that could survive an attack has always been an important measure of future force potential. US concern in the late 1960s over the potential capability of an SS-9 missile modified to carry MIRVs was often expressed in terms of the number of Minuteman silos that could survive such an attack. Because existing Soviet forces did not possess a significant capability against hardened targets until the 1970s, this measure has usually been applied to projected and programed forces.

When used to evaluate the capability of previously existing forces, however, this measure can be very misleading. Our estimate of silo vulnerability, because of both reassessment and silo upgrading, has changed substantially. In addition, only recently has an appreciation for the impact of fratricide as a targeting constraint been recognized by the intelligence community.

Fatalities and Industrial Damage. The estimated number of fatalities and amount of industrial devastation were important dynamic measures used throughout the 1960s and early 1970s. The ability of US strategic forces to satisfy the needs of our deterrent policy was often translated into the percentage of the Soviet population that could be killed and the percentage of Soviet industry that could be destroyed by these forces.

These measures are highly dependent on the target base used and on assumptions about nuclear weapons effects. Both the data base used to determine weapons allocations and the understanding of weapons effectiveness have changed substantially over time. In addition, the essence of US strategic targeting has changed, as the newly evolved concept of strategic deterrence has shifted away from emphasis on fatalities as a measure of effectiveness.

Future Considerations

The complexity of the strategic balance--a result of technological improvements and the continued growth of Soviet strategic forces--has further complicated its measurement.* New dynamic measures are being suggested to evaluate the adequacy of US strategic forces and to compare the military potential of the US and the USSR.

Research is under way into the use of mathematical models to measure the force potential that would survive a counterforce strike. The static and quasi-dynamic measures described in this paper could be used to evaluate surviving forces. The significance of strategic weapons in a post-nuclear environment is unclear, however, and is also under study.

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* See "Assuring Strategic Stability in an Era of Detente" by Paul H. Nitze, in the January 1976 issue of *Foreign Affairs,* and "Assuring Strategic Stability: An Alternative View" by Jan M. Lodal, in the April 1976 issue of the same periodical.